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FREQUENCY BAND JUSTIFICATIONS FOR PASSIVE SENSORS

10.0 to 385 GHz

Chapter I

December 1976

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National Aeronautics and Space Administration

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PREFACE

This document presents the frequency allocation requirements for passive sensors utilized in the Earth Exploration Satellite and the Space Research Services. The document is organized into Chapters I and II, Parts A and B.

Chapter I, Part A presents the applications and, in some cases, potential benefits which are applicable to various microwave remote measurements. Since measurements are required simultaneously in multiple frequency bands to adequately determine values of some phenomena, these relationships between frequency bands are presented. The various measurement accuracies, dynamic range, resolutions and frequency needs are also discussed.

Chapter I, Part B presents a band-by-band summary of requirements, unique aspects and sharing analyses of the required frequency bands for passive sensors.

Chapter II, Part A discusses sensitivity requirements of the various measurements and microwave radiometry techniques while Part B provides the detailed band-by-band sharing analyses.

In addition, Appendices I-IV, describe the analytical techniques applied to the detailed sharing analyses. Appendix V, presents a bibliography of publications pertinent to the scientific justification of the frequency requirements for passive microwave remote sensing.

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PART A

FREQUENCY BAND REQUIREMENTS

1. INTRODUCTION

Some of the most difficult problems facing humanity today are the assuring of adequate supplies of food and energy, while at the same time improving and safeguarding the physical environment and the quality of life. The use of remote sensor observations from experimental and operational aircraft and spacecraft platforms is assisting in the solution of these problems by providing data on phenomena that affect the earth and its environment.

Technological advances in the state-of-the-art in remote sensor systems in recent years, coupled with the desire for greater information on the earth, its oceans, and atmosphere, have led to the development and increasing use of a new generation of remote sensor systems operating in the microwave region of the frequency spectrum. These new sensors, called passive microwave sensors, have the capability of providing information heretofore unobtainable with basic imaging techniques such as photography, television, or multispectral imaging used in past remote observations.

In addition to measuring phenomena and collecting data on a number of phenomena important in studies of the earth, oceans and atmosphere, passive microwave sensors can successfully make measurements in virtually any weather conditions, through clouds and during both day and night time periods. Such measurements are possible since the microwave emissions from the atmosphere, and land and ocean surfaces are frequency-dependent. Furthermore, more economical and repetitive measurements can be made over larger geographical areas using spaceborne microwave passive sensors than with the limited, more costly, techniques currently employed.

Passive microwave sensors can provide the quantitative and qualitative data needed by scientists, engineers, managers and users to help solve mankinds' truly great and pressing problems. Microwave applications are numerous, and the information acquired from the microwave passive sensor data can be used for improving and protecting earth and water resources; planning, preserving and utilizing land resources; and monitoring the environment. More specifically, the data from passive microwave sensors can be used for predicting the weather and long-term climatology changes for detecting, quantifying and monitoring water and atmospheric pollution; and for understanding the earth, ocean and atmospheric dynamics. Each of these is important to the sustenance of life on our planet, and space technology and microwave remote sensors can make significant contributions toward this important objective.

2. APPLICATIONS AND MEASUREMENTS

Experiments conducted with passive microwave sensors have indicated specific applications areas which may benefit from analysis of the data acquired with passive microwave sensing observations. These include:

1) Agriculture, Forestry and Range Resources
2) Land Use Survey and Mapping
3) Water Resources
4) Weather and Climate
5) Environmental Quality
6) Marine Resources, Estuaries and Oceans

In the following paragraphs of this section, specific user needs and problem areas of concern are addressed, along with economic benefits and measurement phenomena, to exemplify the important contributions of spaceborne passive microwave observations in solving many of the problems of the earth.

2.1 Agriculture, Forestry and Range Resources

The need for agricultural, forest and range resources to satisfy a growing population generally have been met throughout history, through intensive development of the available land and through technology advances. To keep up with the worlds' population growth and expanding demands, mankind will have to depend on continued technological progress and further development of land resources. Earth-oriented satellites with advanced sensor systems offer an opportunity to provide potential users with informative and useful data concerning world agriculture, forest and range resources.

Agriculture, forestry and range applications are concerned with the planning of land use for food and fiber production, and the management of those resources for the ultimate benefit of producers and users.

Remote sensing technology can assist in the efficient management of the nation's renewable food and fiber resources and provide relevant information on world-wide agricultural conditions. Timely inventory and production estimates are critical to the distribution and consumption of food and fiber resources. Such estimates require knowledge of not only the types, amounts and location of specific commodities of interest, but information regarding the factors which influence the eventual quality and quantity of the output. These factors include the physical conditions of the plants, such as vigor, density, damage, disease and maturity; and environmental parameters such as availability of water, soil type, moisture, salinity and insect infestations.

Potential applications of satellite data in forest management include inventories of forest type, timber volumes by species and size, inventory of logging residues, and evaluation of forest stresses such as insects, diseases and pollution damage. Other potential applications for range management are vegetation mapping, forage production estimation, monitoring effects of range fires, and encroachment of undesirable vegetation.

The annual economic benefits which may be realized by improving crop forecasts, based on yielding better distribution and import/export decisions, is estimated to be from $247 million to $549 million dollars; while the savings for improving rangeland management, timber harvest management and multiple use allocations are reported to be $54.5 million annually.

Continued advancements in sensor technology should provide capabilities for more frequent coverage, increased resolution, and better sensor signature identification to assure maximum user participation. Passive microwave sensors can provide data on several phenomena which will directly contribute to our information needs in this application area. For example, measurements of soil moisture and rain would be invaluable data for farmers, hydrologists, meteorologists and a variety of other users.

The moisture content of the surface soil layer is a key factor in the determination of plant growth and must be known for the effective mangement of crop production and for use as an input to crop yield forecasts. An accurate knowledge of the soil moisture will allow foresters and agronomists to manage crop irrigation and to provide more accurate forecasts of food and forest production. As an indication of the value of conserving moisture or of utilizing an economical irrigation program, it is estimated that the conservation of an additional inch of available water in the state of North Dakota during the growing season could provide $100 million in direct benefits through increased crop production, plus an additional $200 million in indirect income within the state economy.* In addition, moisture content is a prime determinant of the way water is utilized in water sheds, and hydrologists must be knowledgeable of this parameter for the management of consumable water, hydroelectric power and for the preparation of flood forecasts.

The production of crops such as corn, sorghum sugar beets, wheat and potatoes, and the utilization by beef of marginal land, can be increased by more than 30 times** by irrigation. In many regions, irrigation water is provided by underwater aquifiers. If the underwater aquifiers are not replenished, the resource will be depleted. By adequately monitoring soil moisture over a region, irrigation may be scheduled to maximize its effectiveness and conserve valuable water resources. A limited number of programs to schedule irrigation using soil moisture measurements are currently underway. These programs have reduced water consumption by one third in comparison with irrigation on a fixed time schedule -- an

*The Effects of Added Rainfall During the Growing Season in North Dakota, North Dakota State University, June 30, 1974.

**W. E. Splinter "Center-Pivot Irrigation", Scientific American 234, No. 6, 90-00 (June 1976).

estimated potential savings of $100 million annually. The use of spaceborne microwave systems for soil moisture measurements provides a means for management of water resources on a global basis.

The results of previous application studies, and stated user requirements, have identified the measurement parameters considered desirable for obtaining the needed soil moisture data. The repeat coverage needs for soil moisture measurements are one per day with an accuracy goal of 2 percent and a spatial resolution of 2-5 km. The optimum frequencies for soil moisture measurements using passive microwave techniques are in the 1.4 and 2.7 GHz regions. A range of 0-30 percent (dry weight) has been established as the measurement objective.

Rain is another important factor for the agriculture, forestry and range resources management, and measurements from passive microwave sensors can provide much useful data. Rain measurements are also directly associated with soil moisture. Based on user information and measurement studies of rain using microwave sensing techniques, the stated accuracy and resolution requirements for rain measurements are 20 percent and 1 km, respectively. The desired measurement range is from 0-100 mm/hr with a required update rate being from once per hour to once per day. For optimum rain measurements, multiple frequency measurements are needed at the frequencies of 10.7, 15.5, 19.9 and 37 GHz in order to measure different rain rates and achieve the desired 0-100 mm/hr dynamic measurement range.

2.2 Land Use Survey and Mapping

Recent years have seen a growing realization that land is a valuable resource, finite in amount, and that, in the public interest, there should be better planning of the manner in which land is used now and in the future. Some examples of concern are: whether land that is suitable for growing food should be be developed for alternate uses; whether sufficient land is being reserved for parks or other public uses; where to locate power plants, with due consideration for the effects that plants will have on the locality, and for the needs of plants, such as cooling water and access to fuel; and what the long term effects of converting wetlands to human use are.

For land resource management, satellite data may be applied to the inventorying of agriculture land-use, forest type mapping, suburban and urban mapping, soil erosion studies, cartographic mapping, identification and measurement of wetlands, and pollution mapping.

Land applications are concerned with the inventory of land use as an aid in planning for the most effective use of the land and other resources. It involves the production of land use and other thematic maps and charts, and statistical inventory information along with appropriate prediction models that provide information to a variety of users. Such information will be of use to many international, federal, state, and local agencies, and private and public institutions. The degree of usefulness will be dependent upon the availability, accuracy and timeliness of the information. According to land use planners, the current limiting factor in the process of effective land use management and planning is the timely acquisition of relevant data. Specifically, data gathered by current means have limited usefulnesss in the land use planning process because of incomplete coverage, inappropriate scale, poor reliability or lack of timeliness.

Land use planners have estimated that it would cost states, regional authorities and cities approximately $250 million per year over the next decade if conventional means are used for collecting land use information. Remote sensing systems could supply the necessary information at significantly lower cost. For example, recent economic studies in land use planning indicate that economic benefits attributable to satellites over alternative data gathering systems would be in the range from $7.9 to $17 million annually.

Although many of the information needs of users and land use planners can be satisfied with visible and near infrared measurements, the information obtainable by microwave sensors, with the high resolution, all weather, day/night capability they offer, is desired.

The multiple frequency measurement by passive microwave sensors will assist in land mapping and cartography. Lower frequency measurements will provide specific information for vegetation-free cartographic mapping, whereas the higher frequencies will enable differentiation between vegetation zones, non-vegetation and vegetation density. Such information can be closely tied to the determination of land types such as forest or wooded areas, mountain areas, roads, cities, park land, etc., which are primary use designations required by land-use planners.

2.3 Water Resources

Fresh water is one of the nation's most important assets. It is a renewable resource, but must be wisely conserved if we are to have adequate supplies to meet increasing demands. Sound management of water utilization is also necessary if we are not to affect our environmental and ecological balances.

Water quality and water use data are collected throughout the nation by many agencies, for use in water resources management and operational programs.

Water resources applications are concerned with managing the development, use and conservation of water to assure availability for power generation, irrigation, industrial use, municipal water supply and recreation. Included in this application area are water run-off predictions for flood prediction, hydroelectric power generation, irrigation and water consumption management.

The primary application of remote sensing is to provide information for developing and improving hydrologic models. This includes locating ground water discharges and underground sources; monitoring lake and river ice, monitoring lakes, river, and reservoir water quality, assessing flood damage, mapping flood plains, watershed mapping and modeling, snow mapping and monitoring, wetlands mapping and monitoring, and surveying waterways for navigational hazards.

The potential economic benefits of remote sensing from space have been documented in recent studies. For example, it has been estimated that the annual cost savings and increased value in power generation and agricultural water supply based on improved water run-off forecasts would approximate $54.6 million annually.

Passive microwave sensors can make important contributions in this application area. Sensor measurement techniques can be used to determine precipitation volumes, water content, snow melt rate, and changes in soil moisture. Each of those can be important. For example, snow represents a vast hydrologic resource. In the Western United States, up to 80 percent of the usable water comes from snow melt. Snow melt provides the water resource for hydro-electric power generation, irrigation, industrial use, public consumption, and recreation. Accurate monitoring of the amount of water in the snowpack and the rate of release is required for streamflow forecasting. Adequate streamflow forecasts during snow melt are required for the management of reservoir levels to store water and prevent flooding.

In regions where the primary water resource is snowmelt, water that is lost due to inadequate storage facility management cannot be recovered for future use. Remote means are required to determine snow water content and the amount of water within the snow pack. These measurements must be made separately for each drainage basin. Satellite borne radiometers with a 2-5 km spatial resolution are required to provide the service on a global basis.

Multiple frequency measurements are desired for snow depth, extent and water content measurements. The desired frequencies for passive microwave sensing of snow include 1.4, 2.7, 10.7, 19.9 and 37 GHz. Users have indicated an update rate of one per day with an accuracy of 2 percent, and a range from 0-20 percent free water content.

Lake ice measurements represent another potential information source for water resource scientists, managers, and users. Large lakes such as the Great Lakes are valuable national resources, not only as water sources, but as key transportation routes for bulk commodities. In northern regions, the lakes may be frozen for a significant period of time, a factor which limits their usefulness. A better understanding of the lake ice morphology is necessary to develop techniques to extend the shipping season; an extension of the St. Lawrence Seaway season for even a few weeks would have a significant economic impact.* Remote observations of the thickness and structural changes in the ice are required to forecast ice breakup and weak points for ice breakers. Microwave radiometers provide a means of sensing the structural properties of the ice under both clear and cloudy conditions,** thus providing a means for the effective management of this aspect of water resources. The spatial resolution required for measurements is 2-5 km, with a daily update rate.

2.4 Weather and Climate

The use of satellites in the observation and prediction of the earth's weather represents one of the earliest of all space applications. Many advances have been made in long range weather and climate forecasting and weather hazard prediction on the basis of the satellite acquired data, but significant improvements in this discipline area can be realized through microwave remote sensor systems capable of performing long term observations.

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* Helewicz, J., 1976: "Arctec Would Corral Sea Ice", The Baltimore Sun, June 27, 1976 (Section K).

** J. C. Blinn, III, "Microwave Measurements of Ice Thickness", Environmental Research & Technology, Inc., Final Report JPL Contract 953748, Concord, Mass. 01742, February 1975.

Long range predictions are now receiving much attention, and their importance justifies continued emphasis. Information from satellite systems, combined with earth-based observations, will make it possible to monitor, on a long-term basis, many of the physcial factors considered by climatologists to be critical in establishing the mean and statistical states of the atmosphere. Many of these factors are manifested in effects on the radiation balance of the land-ocean-atmosphere system -- included are the measurement of solar radiation, the determination of the earth's radiant energy retention capability (albedo), the measurement of outgoing infrared emissions, and the heat content of the mixing layer at the surface of the oceans. These measurements will ultimately be needed to relate the earth's energy budget to measurements of the states of the atmosphere, such as the nature and the distribution of cloud cover, and the vertical structure of temperature and water vapor.

Prediction of local weather for periods of up to two hours is also becoming increasingly important to the decision-making processes of a wide variety of users in the construction, offshore drilling and other industries. Knowledge of weather and climate also is essential in assuring adequate food supplies. For example, prediction of soil moisture, rainfall, snow, snow melt and run-off would be useful in agriculture and hydrology.

The wide demand for present weather data and the willingness of users to invest in the necessary ground equipment has been demonstrated by the extensive use of the Automatic Picture Transmission (APT) system, now part of the NOAA satellite series. Over 1000 users purchased or constructed specialized ground equipment in order to receive APT pictures. This represents a total voluntary expenditure of approximately $10 million. Because this information is obtained from low altitude satellites, it is available at any given location about twice daily. The continuous flow of data from planned geostationary satellite systems could increase many fold the availability of present weather information. The requirement for rapid response essentially precludes the centralized processing now in use. Many users will need low-cost receiving and processing terminals of their own. An advanced geostationary satellite, with high resolution imaging and sounding capability (for which the technology is being developed), would permit such applications.

New needs and economic benefits related to weather and climate prediction are much broader than heretofore believed, and involve a much broader range of users than just the weather forecasting community. The weather not only affects individuals on a daily basis, but affects groups of users as well. For example, in agriculture, farmers throughout the world are concerned with weather and a number of decisions are made by farmers daily regarding planting, spraying, irrigating, plowing and harvesting. In a localized case study, it was found that the economic benefits to hay users in the state of Wisconsin alone was $88 million per year. These figures are based on optimum predictions and decisions that are weather dependent. Another example is the highway construction industry which needs accurate predictions for decisions such as when to pour concrete, do earth work and when construction workers cannot work due to weather conditions.

In another benefit study, cargo and shipping losses caused by weather were estimated to be $500 million annually. Representatives of the maritime community involved in the study concluded that improved wave and weather forecasts, which space systems might make possible, could permit important reductions in these losses. They further concluded that improved routing which space-based navigation could make possible, would permit important additional savings in the $450 million fuel cost currently experienced in transatlantic service by the U.S. flag fleet. World-wide, such benefits could be accrued by all shipping nations.

Weather and climate applications include the three major areas of: 1) Weather Prediction, 2) Climate Monitoring and Prediction, and 3) Weather Danger and Disaster Warning. Remote sensing techniques can be used to determine the actual structure of the atmosphere globally which, when supplemented by simulation techniques, models and other observations, will provide the required data for weather forecasts. Other applications include monitoring indicators of regional and global climate changes, including solar inpout, radiation budget, ocean-atmosphere interactions and atmospheric gas and particulate variability. For Weather Danger and Disaster Warning, remote sensing systems can be used for continuous observations of atmospheric features to permit early identification and quantitative measurement of atmospheric conditions condusive to the formation of tornadoes, thunderstorms and hurricanes.

Important measurement parameters that microwave sensing systems can contribute to the weather and climate applications are discussed in the following paragraphs along with the specific requirements.

Microwave observations at frequencies below 30 GHz are relatively insensitive to clouds and are useful for surface observations under both clear and cloudy conditions. Clouds, especially large areas of stratiform clouds, are detectable at higher microwave frequencies; these cloud observations are required for use in weather and climate forecasts. The effects of clouds on measurements made at the higher microwave frequencies must also be known in order to interpret the measurements correctly.

Cloudiness provides a tracer of atmospheric motion; it is important for studying climatic changes and is an important input for studies of atmospheric dynamics. Information on cloudiness is equally important for the development of future short-range forecasting schemes. Current infrared temperature sounding systems are adversely affected by clouds, and information from combined microwave and infrared sensors are required to interpret the data adequately in order to provide temperature profiles.

Cloud measurement requirements specified by users include a desired range of 0-3 $gm/m^2/km$ and an accuracy of 0.3 $gm/m^2/km$. A spatial resolution of 1 km is required. The desired frequencies for passive sensing are 37 and 90 GHz, and update information is needed every 6 hours. A number of competing effects which must be corrected for are soil moisture, snow, lake ice, sea state, surface temperature, water vapor and atmospheric temperature.

Rain is another important phenomena that can be measured by passive microwave sensors. Rain is an important water resource for agriculture and provides water for industrial use, public consumption, and recreation; it can also represent a potential hazard due to flooding. Rain is an important tracer of atmospheric processes, and provides an indication of the latent heat energy release that drives atmospheric circulation. Rainfall data are required overland for water management and over the oceans for weather and climate forecasts.

The accurate measurement of rainfall on a global basis is possible using multifrequency microwave radiometers that provide nearly constant surveillance of all areas.* Observations of rain as a tracer of atmospheric dynamics can be routinely made using microwave observations both overland and over the oceans. These latter measurements are required only one to four times per day for input to weather forecasting schemes.

Multiple frequency measurements for differing rain rates are desired. Measurements can be performed at 10.7, 15.5, 19.9 and 37 GHz. The user requirements include an overall range requirement of 0-100 mm/hr with a 20 percent accuracy. A spatial resolution of 1 km is desired with an update rate of once per hour to once per day. Other parameters or effects relating to these measurements include soil moisture, snow, lake ice, sea state and surface temperature.

Water vapor also plays an important role in the energetics of the atmosphere and climate behavior. Water vapor profile measurements are required for short-range forecasts, and total integrated water content measurements are required for long-range and climatological forecasts.

*Radiometric measurements at a single frequency have a limited dynamic range. To extend the dynamic range simultaneous measurements must be made at a number of frequencies between 10 and 37 GHz. If overland measurements are to be made, observations should be made at even lower frequencies.

Water vapor profiles may be remotely measured by either infrared or microwave radiometers Microwave radiometers provide the only means for making observations during periods of cloudiness. For adequate inversion or interpretation of the microwave water vapor observations, radiometric measurement of cloud water content is also required. Also, since absorption and emission by atmospheric water vapor occurs with varying intensity over the entire microwave frequency region, observations of the surface at other frequencies are affected by water vapor, and measurements of at least the total precipitable water are required for the correction of other measurements.

There are classes of satellite observation systems that are required for weather and climate applications. Low orbiting satellite observations with downward (nadir) viewing radiometers in the 15-32 GHz range are necessary to provide data with high spatial resolution close to the earth's surface. Geostationary satellite observations in the 182-185 GHz range are necessary to provide data with high update rates and adequate spatial resolutions. Limb scanning (above the horizon) observations on low orbiting satellites are also required in order to provide water vapor profiles in the stratosphere. Limb scanning observations will utilize the 182-185, 320-330 and 375-585 GHz ranges.

The requirements for low orbiting nadir observations include a 0-7 gm/cm^2 range for total precipitable water, with an accuracy of 0.3 gm/cm^2, and a spatial resolution of 2 km for over-land measurements and 20 km for measurements over the ocean. Multiple frequency measurements are essential to nadir profile measurements, and the bands of interest include 15.5, 17.9, 19.9, 21.2, 22.2, 24.0, and 31.5 GHz. The desired update rate for these measurements is twice per day. There are several competing effects which must be considered which include soil moisture, snow morphology, lake ice, sea state, sea ice, clouds, rain and atmospheric temperature.

The observation requirements for geostationary nadir measurements are somewhat different although the range and accuracy are the same as in low orbiting nadir observations. A spatial resolution of from 20-100 km is adequate with an update rate of four times per day. Multiple frequency measurements are required within the band of 182-185 GHz to provide profile data. Competing effects with these measurements include temperature, clouds and rain.

Measurement requirements for the low orbiting limb sounder observations include a range of .001-.1 gm/m^2 and an accuracy of 0.001 gm/m^2. A spatial resolution of 100 x 300 km (horizontal) and 1 km (vertical) is required. Multiple frequency measurements within the band are desired over the range of 182-185, 320-330, and 375-385 GHz. The update rate specified is four times per day. The only strong competing effect for these measurements is temperature, which is discussed in the following paragraphs.

A large number of temperature and wind profile measurements at locations distributed uniformly over the surface of the earth are required for weather forecasting. At a minimum, temperature profile measurements are required at a large number of locations. At present, balloon carried sensors (radiosondes) provide the required observations over land areas, and satellite-borne infrared radiometers are used to generate temperature profiles over the oceans. However, infrared observations are often contaminated by clouds, while microwave data can provide the required data under all weather conditions.

Temperature soundings are calculated by inverting radiometric observations made simultaneously at a number of frequencies within the molecular oxygen rotation lines between 50 and 70 GHz or near the isolated line at 118.75 GHz. Observations are required at different frequencies to provide different altitude weighting functions* for sensing temperature variation with height. Observations made at frequencies with high absorption values (near the peak of the lines) provide information about

*Staelin, D. H. (1969): "Passive Remote Sensing at Microwave Wavelengths", Proc. IEEE, 57 427-439.

temperature high in the atmosphere; observations at frequencies with less absorption (further from the peaks of the lines and typically in the valleys between the lines) provide information about temperature at lower altitudes.

There are three classes of satellite observation systems that are required. Low orbiting satellite observations with downward (nadir) viewing radiometers in the 50-70 GHz region are necessary to provide data with high spatial resolution close to the earth's surface. Geostationary satellite observations at frequencies between 114 and 124 GHz are necessary to provide data with high update rates and adequate spatial resolution. Limb scanning (above the horizon) observations on low orbiting satellites are required to provide temperature profiles in the stratosphere. Limb scanning observations will utilize frequencies in the 50-70 GHz region as well as those above 100 GHz

The requirements for the low orbiting nadir observations include a range of -70 to +30°C with an accuracy of 1°C. A spatial resolution of 2-20 km is desired with an update rate of twice per day. Multiple frequency measurements are required, and more than four separate frequency bands in the 50-70 GHz band are needed to provide a range of weighting functions for different altitude measurements. Effects which compete with these low orbiting nadir observations include clouds, rain and water vapor.

For the geostationary nadir observations a -70° to +30°C range is required with an accuracy of 1°C. A spatial resolution of 20-100 km is essential, with an update rate of four times per day. Multiple frequency measurements within the band of 114-124 GHz are essential for profiling. Several competing effects exist which include water vapor, clouds, and rain.

The requirements for low orbiting limb sounding include a range of -70° to +10°C with an accuracy of 1°C. A spatial resolution of 100 x 300 km (horizontal) and 1 km (vertical) is required, with an update rate of once per day. Multiple measurements are required within the bands of 50-70 GHz and 110-126 GHz for profiling. The primary competing effect in these measurements is water vapor.

2.5 Environmental Quality

There is major evidence that the earth's environment is being adversely affected by man. The growth of the earth's population, the tremendous increase in industrial activity, and the concentration of people in cities and expanding metropolitan areas have brought major problems in maintaining the quality of the physical atmosphere and an adequate supply of quality water.

Laws recently enacted at the federal and state levels, together with action programs at the federal, state and local government levels and by industries, are moving the nation at an accelerated rate to a cleaner physical environment. An implementation schedule has been established that calls for most of the goals to be met within 10 years. It has been estimated by environmental specialists that in excess of $100 billion will be spent during the next decade for pollution control.

Current and evolving remote sensor systems could contribute to achieving the national environmental goals, and meet the needs of major users of environmental quality data. Substantial progress has been made in developing sensors and systems for air quality monitoring in the stratosphere. In contrast, however, progress in developing sensors and systems for monitoring the lower atmosphere and monitoring water quality is lagging. There is an immediate need to use state-of-the-art technology and to place in operation improved and expanded air and water quality monitoring programs to meet regulatory requirements.

The troposphere is the lowest major layer of the atmosphere, extending from the earth's surface to an altitude of about 12 km. It is in this lower layer of the atmosphere that most of the important processes affecting atmospheric pollution, as well as weather, occur. Most of the first-order effects of airborne pollutants experienced by man, plants, and animals are highly dependent upon the dispersion and dilution capacity of the troposphere. A temperature inversion layer just above the troposphere acts to some extent as a cap or lid on the mixing layer. The most immediate air quality problems involve sensing and controlling the pollutants in the layer of the troposphere nearest the earth.

Sensors on the earth's surface, in aircraft and in spacecraft can be used for monitoring the troposphere to assess, on both regional and global scales, the impact of air pollution and of air quality control. Passive microwave sensors can provide capabilities for all weather, day and night measurements, and for measuring the vertical distribution of pollutants from the ground up.

In the stratosphere, the region of the atmosphere from about 12 km to 50 km above the surface of the earth, space-borne sensors can also contribute valuable data. The stratospheric ozone layer filters ultraviolet radiation from the sun that is harmful to most forms of earth life. There are growing concerns about the potential for effecting significant changes in the world-wide climatic conditions through the introduction of both trace gases and particulates into this protective barrier of the planet. Several basic properties of the stratosphere make it sensitive to the injection of trace gases and particulates of both man-made and natural origin. Since photochemical processes that determine the ozone content are not well understood, it is conceivable that the introduction of new materials, or the increase in quantity of chemical forms, leading to new equilibrum values could significantly alter the protective ozone barrier.

Over the next decade, emphasis must be given to monitoring the environmental quality of the stratosphere on a global scale with emphasis on measurements of stratospheric species, both gases and aerosols, and on the species involved in ozone chemistry. Additional measurements should be directed at determining the impact of man-made pollutants on significant stratospheric natural processes.

Measurements of the concentrations of atmospheric trace constituents and their variation in space and time are required to evaluate the effects of man on the stratosphere and troposphere. Passive microwave remote sensing can provide information about ozone (O_3), nitrous oxide (N_2O) and carbon monoxide (CO). The current controversy over the use of aerosol sprays and the depletion of the ozone layer arises in part from a lack of data on ozone content and variation. A real depletion of the ozone layer may cause an increase in the occurrence of skin cancer. Microwave observations are required to provide daily observations of ozone concentrations. Similarly, the trace constituents N_2O and CO should be monitored to establish background levels to assess the effects of these pollutants.

Molecular oxygen, water vapor, ozone, nitrous oxide, and carbon monoxide all have rotation lines in the 100 to 300 GHz region. Limb scanning observations of emissions at frequencies centered on the rotation lines and in the valleys between lines are required to provide altitude distributional information on the trace constituents in the stratosphere and troposphere. The spatial resolution requirements for limb scanning of ozone, nitrous oxide and carbon monoxide measurements are 100 x 300 km (horizontal) and 1 km (vertical). Update rates required for ozone are 1 per day, while the specified rate for nitrous oxide and carbon monoxide are once per week. The required line frequencies for ozone are 110.83, 124.09, 184.38, 235.71, 237.15, 239.09, and 364.43 GHz. For nitrous oxide, measurement frequencies include 125.61, 150.7, 175.86, 200.97, 226.1, 251.2, 276.3 and 301.4 GHz. The required line frequencies for carbon monoxide are 115.3, 230.5, 345.80 GHz. The primary competing effect for each of these is water vapor.

2.6 Marine Resources, Estuarine and Oceans

Water has a fundamental impact on the welfare of mankind and its very existence. Water covers more than two-thirds of the earth's surface. The oceans dominate the earth's weather systems and are the source of vast quantities of food and other natural resources. Furthermore, ocean commerce is of crucial importance to man's capacity to maintain or enhance his quality of life.

Remote sensing technology can provide data for, and assist in:

(1) the efficient management of living marine resources,

(2) the efficient and effective management of activities within estuarines and coastal zone regions,

(3) the effective use of the oceans as transportation routes, and

(4) the meaningful contribution toward the advancement of the basic sciences of marine biology and oceanography.

Estuaries and coastal zones play an important role in the productivity of coastal regions by serving as home, nursery, and breeding grounds for many species of fish and shellfish that are important as food crops. Practically all sports fish and 65 percent of all commercial fish are estuarine dependent,* spending at least some of their life in estuarine waters. The habitat for these species is principally determined by the salinity and temperature of the waters. Oysters, for example, can tolerate a wide range of salinity but produce best within a limited salinity range. Large influxes of fresh water stimulate shrimp stock perhaps by salinity change, and perhaps by the nutrients carried by the fresh water.

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* Report by the Secretary of the Interior to the U.S. Congress, "National Estuarine Pollution Study", Senate Doc. 91-58 (1970).

From 1959 to 1969, imports of fishery products accounted for 19 percent of the total deficit in the U.S. balance of payments. In the late 1950's, the annual deficit was on the order of several hundred million dollars. Currently about 70 percent of fishery products used in the U.S. are imported, and the deficit is about $1.5 billion per year. An increase in the productivity and protection of fisheries in our own coastal waters would reduce U. S. dependency on other nations. Remote sensing techniques can be of benefit in (1) understanding fisheries-related biology to conserve fish stock and establish maximum sustainable yields for the stocks, (2) enforcing international and other conventions and agreements related to fisheries, and (3) forecasting environmental conditions best suited for specific species of fish to determine the most likely location of schools.

Remote measurements of salinity are required to monitor habitat change and to forecast fish and shellfish population levels. Microwave measurements are required to provide the salinity data under both clear and cloudy conditions. Measurements of surface salinity within the small confines of estuaries implies a spatial resolution limitation for the sensors. However, microwave systems can provide salinity data integrated over areas with a characteristic length of 2-5 km, and the observations are useful for assessing and monitoring habitat change.

In the open ocean, salinity shows relatively small change with time and location. Local changes, however, can occur after major storms or as a result of large-scale circulations. Salinity and temperature serve as tracers of these large-scale ocean currents, and their measurement is important for climate forecasts. Microwave radiometry provides the only routine method for the acquisition of salinity data of the open oceans on a global basis.

The specified range for estuarine salinity measurements is 10-35 parts per thousand, with an accuracy of 2-5 parts per thousand, a spatial resolution of 2-5 km. The optimum frequency is 2.7 GHz. An update rate of once per week is required. For ocean salinity the range is 30-36 parts per thousand with an accuracy of 0.2 parts per thousand. The optimum frequency for these measurements is 1.4 GHz, with a 20 km spatial resolution. The competing effects for such measurements include surface temperature, sea state, water vapor, clouds and rain.

Microwave passive remote sensors can also provide data on surface temperature. The habitat of fish and shellfish within an estuary and coastal zones is determined principally by the salinity and temperature. The preferences of some commercial fish species for a limited range of water temperatures is well known to fishermen. The rapid detection of coastal water mass boundaries (ocean fronts) and coastal upwellings of nutrient rich, cold subsurface water is required for the optimum deployment of fishing vessels. Detection of thermal anomalies is also required for warning of natural hazards to coastal regions such as the so-called "red tide", a sudden growth of toxic dinoflagellate blooms which seriously affect the economy of the shellfish industry. Also, water temperature is a tracer of water circulation, and as such can be used for the detection of thermal pollution and the enforcement of environmental regulations.

Ocean surface temperatures are also measureable. These temperatures act as a tracer of ocean circulation and can be used to identify or mark upwellings where colder, nutrient rich water is forced to the surface. Temperature distributions affect the abundance and distribution of marine organisms, which in turn affect the commercial fish population. Routine, clear and cloudy weather observations of the variations in sea surface temperature are needed for the optimum deployment of fishing vessels. The data are also required for long-range weather forecasts. Satellite-borne microwave passive remote sensing of sea surface temperature can provide the routine observations over the entire globe that are needed for weather forecasting and ocean fishery resource management.

Estuarine, coastal and ocean surface temperature measurements are needed over a range of 0-30°C to an accuracy of 0.5°C. The spatial resolution for estuarine measurements is 2-5 km at a frequency of 5.0 GHz. Update rates of once per day are essential. For ocean surface temperature measurements, a 20 km spatial resolution is required, with the optimum frequency being in the 6.5-7.0 GHz region. The competing effects in these measurements are sea state, water vapor, clouds, and rain.

The term "sea state" has been used widely for describing the characteristics of the ocean surface as modified by the wind. It is also known that a marked variation in microwave brightness temperature results from variations in the ocean surface conditions. Thus, there is the potential for huge savings through the use of microwave radiometers for mapping the sea state over large areas on a routine basis. For example, fixed installations such as offshore drilling platforms placed in estuaries or in the vicinity of continental shelves are exposed to the huge stresses caused by high seas. Thus, sea state data are needed for hazardous situation warning and for the compilation of statistical data for the design of structures to withstand the stress. The current high failure rate of offshore structures is a testimony to the requirement for improved data. Passive microwave sensing systems have the capability of providing the required sea state data under nearly all weather conditions on a routine, global basis. Moreover, since the sea state affects measurements of salinity and temperature and the detection of oil slicks, sea state measurements must be made in order to interpret correctly the observations at other frequencies.

Microwave remote passive sensing of sea state at a number of frequencies over the open ocean can provide surface wind speed data under all weather conditions for long- and short-range forecasts of weather and wave conditions. It is known that rough seas can seriously reduce the speed of ocean transports. Many of these ships have operation costs in excess of $50,000 per day; consequently, knowledge and forecasts of sea state which result in more rapid and improved transportation is of enormous economic benefit.

Major ocean storms such as typhoons and hurricanes can be remotely sensed and their position determined from the spatial wind speed pattern. This information is critical for typhoon and hurricane warning. The general clouds and rain patterns associated with tropical storms can be sensed with visual, infrared and microwave radiometers. Only microwaves, however, provide all the weather surface windspeed sensing capability required to assess the severity of the storm. As noted previously, sea state measurements are required to correct measurements of salinity and water surface temperature, and overwater observations of clouds, water vapor profiles, and atmospheric tempratures.

The optimum frequencies for sea state (wind speed) measurements are 10.7 and 19.9 GHz. The measurement range for estuarine sea state (wind speed) measurements has been specified to be 0-30 m/sec. with an accuracy of 2 m/sec. A spatial resolution of 2-5 km is needed, with an update rate of once per day. For ocean sea state measurements, a range of 0-40 m/sec. at an accuracy of 2 m/sec. is required. A 2-20 km spatial resolution is needed, with an update rate of once per every 6 hour period. The basic competing effect in these measurements is rain.

Ice extent, thickness and type are also measurable at microwave frequencies. Ice presents a hazard to marine transportation in various parts of the continental U.S. and in Alaska. The Great Lakes, the U.S. central river system, and New England are becoming increasingly important to the transportation of commodities. Nearly all iron ore which moves in the Great Lakes region is carried by ship. Significant amounts of wheat, oil products, coal, and finished goods also move across the region by ship. Most vessels operating in the U.S. are not designed to operate unaided through ice-covered waters, and ice-breaking service is provided, usually by the federal government (U.S. Coast Guard). Therefore, capabilities to determine ice coverage, clear water passages, pressure ridges, and ice thickness are important to success in extending the navigation season. An interim report* on the extension of the St. Lawrence and Great Lakes navigation season beyond the December 15 closing date shows the following estimated economic gains:

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*U.S. Army Corps of Engineers. Great Lakes Navigation Season Extension. Winter Navigation Board, Special Status Reports, U.S. Army Corps of Engineers, July 1974.

	Gain in Millions of Dollars		
Navigation season extended to	Jan. 31	Feb. 28	Year round
By 1975	40	58	68
By 1985	85	123	145

These gross estimates are based on a number of factors including improved ice surveillance, better data analysis and better prediction, all-season aids to navigation, and increased icebreaking activity.

In the Arctic and Antarctic, ice-breaking has historically been conducted in support of scientific investigations and, to a limited degree, in military operations. Recent discovery of oil deposits on the Alaskan north slope, coupled with the political and economic ramifications of a dependency on Middle East oil supplies, has spurred activity in the far north. Scientific and geological surveys, commercial oil drilling, ocean transport, and supporting icebreaking requirements in high latitudes will place increasing emphasis on all-weather sensing to predict ice extent, polynyas, ice thickness, pressure ridges, and the discrimination of new ice from multi-year ice.

Microwave measurements can provide ice thickness observations under both clear and cloudy conditions. Remote sensing at visual and infrared frequencies provide information on ice location, but only microwave sensors can provide observations during the period of ice breakup when clouds regularly obscure the surface. Microwave measurements provide the only means to sense ice thickness quantitatively. Data is required to provide this information on a routine basis for all global regions north of 50°N and south of 50°S, where sea ice is important to navigation.

The measurement requirements for ice thickness include a range of 0-1 meter and an accuracy of 0.2 meters. A 20 km spatial resolution is needed and an update rate of once per day is desired. The optimal frequency for ice thickness measurements is 1.4 GHz. Ice type measurements are also desired. A spatial resolution of 2-20 km has been specified, with a once per day update rate. Multiple frequency measurements are needed for ice type discrimination, with the primary frequencies being 10.7, 19.9 and 37.0 GHz. The primary competing effects in ice thickness and ice morphology measurements are rain and snow cover.

Some forms of sea pollution are also measureable at microwave frequencies. An example is marine oil spills, an important form of pollution. The oil affects the production of the smaller marine organisms that develop near the ocean surface. These small marine organisms are important links in the food chain leading to commercial fish stocks.

Also, oil floating on estuarine water is an insidious form of pollution that affects commercial fishing, wildlife habitat, and recreation.

The USCG has observed marked decreases -- up to 25 percent -- in the number of oil spills when continued surveillance of critical areas has been employed.* Although much of this decrease can be attributed to increased attention to handling and transfer methods, the fact that better and more complete surveillance is being conducted tends to dissuade the intentional polluter. The cost of daily observation of certain harbors and waterways with existing vessels and aircraft by the USCG is estimated to be between $2 million and $4 million annually. The cost may exceed $18 million annually if a dedicated system for surveillance of pollution is extended to all major U.S. continental lakes and coastal waters. At present, high-resolution radar, imaging microwave radiometers, and multispectral low-light-level television are being installed on aircraft for surveillance in low-altitude flights. It is estimated that yearly costs could be decreased by about one-third or one-half through the use of sensor systems which can detect surface oil of 1,000 m^2 or greater.

Passive microwave sensors on low orbiting satellites are capable of detecting and measuring the thickness of oil spills* of more than 0.2 km spatial extent. Microwave measurements can

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*Gerhard, Glen: A Study of the Cost Effectiveness of Remote Sensing Systems for Ocean Slick Detection and Classification. National Sea Grant Program, U.S. Coast Guard, Washington, D.C., 1972.

make timely oil spill detection under both clear and cloudy conditions. Timely detection is important in remote regions, both for the effective enforcement of environmental regulations and for the initiation of effective corrective action.

Passive microwave observations with a resolution of 2 km are required to monitor the occurrence of marine oil spills on a daily basis. The frequencies necessary for these measurements are 37.0 and 90.0 GHz. The competing effects are sea state, rain and water vapor.

2.7 Summary

A review of the applications, remote sensor needs and measurement requirements for passive microwave sensors outlined in the previous paragraphs indicates that a natural relationship can be established. Table 1 is a matrix of the relationships of the various applications areas and the types of information which would benefit each application area. From this chart it can be seen that much of the data from the measurements and phenomena of interest can be used in a number of applications areas.

MAJOR APPLICATIONS AREAS	Measurement Phenomena																	
	Terrain Imaging	Soil Moisture	Snow Morphology	Lake Ice	Salinity	Surface Temperature	Sea State	Oil Slick	Ice Thickness	Ice Morphology	Clouds	Rain	Water Vapor	Temperature	H_2O	CO	N_2O	O_3
Agriculture, Forestry and Earth Resources		●	●	●							●	●	●					
Land Use Survey and Mapping	●																	
Water Resources		●	●	●	●	●	●	●			●	●	●					
Weather and Climate						●	●				●	●	●	●				
Environmental Quality					●			●							●	●	●	●
Marine Resources, Estuaries and Oceans			●	●	●	●	●	●	●	●	●	●		●				

TABLE 1

Relationship of Measured Phenomena to Major Applications Areas

3. MEASUREMENT CONSIDERATIONS AND FREQUENCY REQUIREMENTS

Remote sensing is the observation, measurement and interpretation at a distance of the physical environment through the use of electromagnetic radiation. Physical parameters that can be determined remotely are spatial distribution, spectral distribution, polarization, temporal variation, and variations of the above factors with angle of observation.

In the microwave region, 1.0 to 300 mm (300 GHz to 1 GHz), thermal emission, which is dependent on the emissivity and physical temperature of matter, can be observed.

Radiometers measure the apparent temperature averaged over all objects within the antenna's coverage. Apparent temperature is the overall measured "brightness" temperature from all objects. Considering only one object at temperature T, and no intervening atmosphere, the brightness temperature T_B equals:

$$T_B = \varepsilon T$$

where ε is the emissivity of the object.

Since an earth-viewing radiometer measures radiation emitted and reflected from the earth and the atmosphere, measurement of one is complicated by the other's presence. Also, every form of matter has a differing emission spectrum. Molecules, for example, have emission (and absorption) spectrum relatively narrowly confined about a frequency which is determined by the quantum mechanic relationships for that molecule. On the other hand, matter which is composed of many molecules, such as land, has a very broad emission spectrum which is the sum of the complex interactions of all the molecules in the particular matter.

Theoretically, the best method of recognizing various forms and concentrations of matter, would be to utilize a spectrum analyzer that covers the whole microwave spectrum. Since this is impossible, sensing is necessary in frequency areas where the phenomena exhibit high responses relative to competing effects. For example, when measuring surface phenomena such as soil moisture or sea state, the time varying absorption effects of atmospheric water vapor can mask the desired measurements. If, however, the water vapor concentrations and hence absorption effects, were measured separately, then such masking effects could be removed. Consequently, there is an interrelationship between all phenomena that if accounted for, would improve the accuracy and utility of the measurements. Table 2 illustrates the interrelationships for various phenomena. The letter P in the Table indicates that the phenomena exhibits a strong emission at the designated frequency and, hence, is considered a primary measurement. Table 3 presents a matrix of these desired measurements and various competing effects which need to be simultaneously measured in order that highly accurate primary measurements can be made.

TABLE 2
FREQUENCY BANDS FOR THE INVESTIGATION OF SURFACE AND ATMOSPHERIC **PHENOMENA**

MEASUREMENTS

FREQUENCY BAND GHz	Land: Soil Moisture	Land: Snow Morphology	Land: Lake Ice	Estuary: Salinity	Estuary: Surface Temperature	Estuary: Sea State	Estuary: Oil Slick	Ocean: Salinity	Ocean: Surface Temperature	Ocean: Sea State	Ocean: Ice Thickness	Ocean: Ice Morphology	Ocean: Oil Slick	Atmosphere: Cloud	Atmosphere: Rain	Atmosphere: Water Vapor	Atmosphere: Temperature	Trace Constituents: CO	Trace Constituents: N_2O	Trace Constituents: O_3
1.300-1.427	P	P						P		P	P									
2.6[illegible]-2.70	P	P		P																
4.95-5.00					P															
6.425-7.250									P											
10.6-10.7		P	P			P				P		P			P					
15.3-15.5															P	P				
[illegible]-17.9																P				
19.7-19.9		P	P			P				P		P			P	P				
21.0-21.2																P				
[illegible]-22.4																P				
23.6-24.0																P				
31.3-31.5																P				
36.0-37.0		P	P				P					P	P		P					
5[illegible].2-50.4																	P			
52.[illegible]-54.25																	P			
5[illegible].9-55.1																	P			
5[illegible].05-5[illegible].55																	P			
57.5-5[illegible].5																	P			
62.[illegible]-63.0																	P			
8[illegible].0-92.0							P						P	P						
100.0-102.0																			P	P
105.0-126.0																	P	P	P	P
150.0-151.0																			P	
174.5-176.5																			P	
182.0-185.0																P				P
200.0-20[illegible].5																			P	
225.0-240.0																		P	P	P
250.0-252.0																			P	
275.0-277.0																			P	
300.0-303.0																			P	
320.0-330.0																P				
340.0-350.0																		P		
360.0-370.0																				P
375.0-385.0																P				

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TABLE 3
COMPETING EFFECTS IN THE INVESTIGATION OF SURFACE AND ATMOSPHERIC PHENOMENA

COMPETING EFFECT

MEASUREMENT	Soil Moisture	Snow Morphology	Salinity	Surface Temperature	Sea State	Ice Thickness	Ice Morphology	Oil Slick	Cloud	Rain	Water Vapor	Temperature	CO	N_2O	O_3
Soil Moisture									X	X	X				
Snow Morphology									X	X	X				
Lake Ice		X							X	X	X				
Salinity				X	X				X	X	X				
Surface Temperature					X				X	X	X				
Sea State									X	X					
Ice Thickness		X					X								
Ice Morphology		X								X					
Oil Slick					X					X	X				
Cloud	X	X		X	X		X			X	X	X			
Rain	X	X		X	X		X								
Water Vapor	X	X			X		X		X	X		X			
Temperature									X	X	X				
H_2O											X				
CO															
N_2O											X				
O_3											X				

Those frequencies in the 20-24, 50-70, and above 100 GHz provide atmospheric measurements. The frequencies chosen allow for the profiling of the constituent of interest through measurement on and around molecular resonance lines. Profiling measurements allow for determination of vertical distributions of molecules of interest. Such profiles provide information on such phenomena as fluorocarbon migration to the stratosphere and the consequent interaction, and depletion, of ozone.

A number of frequencies are also specified for rain measurements - these are required to provide an adequate dynamic range for high spatial resolution observation over a wide range of rain rates.

Since land and sea phenomena to be measured produce broadband responses, the frequency of the center of each band is not critical. What is important is the general location of each band in the frequency domain, due to the high sensitivity to the phenomena, and the number of separate frequency bands. Only 11 bands have been requested for land and sea phenomena.

In conclusion, passive microwave remote sensing is a powerful new tool for the management and conservation of the earth's resources. It is important for future generations that the required frequency bands be protected, to the highest practical limit, from significant contamination. The following sections address this problem through sharing analyses with current and proposed services in the requested passive sensing bands.

CHAPTER I

PART B

SUMMARY OF REQUIREMENTS, UNIQUE ASPECTS
AND SHARING ANALYSES OF REQUIRED FREQUENCY BANDS

SECTION 1

FREQUENCY BAND 10.6 - 10.7 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

10.6-10.7 GHz BAND

1.1 ALLOCATIONS

The existing allocations and proposed changes in the 10.6-10.7 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
10.6-10.68	~~FIXED~~ ~~MOBILE~~ RADIO ASTRONOMY Radiolocation SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) 404A	
10.68-10.7	RADIO ASTRONOMY SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) ~~405B~~	
	NON-GOVERNMENT	
10.6-10.68	FIXED MOBILE (except aeronautical mobile) RADIO ASTRONOMY Radiolocation ~~404A~~	
10.68-10.7	FIXED MOBILE (except aeronautical mobile) RADIO ASTRONOMY ~~405B~~	
SUP 404A	405B	

1.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Snow morphology (primary),
2) Lake ice morphology (primary),
3) Estuarine sea state (primary),
4) Sea ice morphology (primary), and
5) Rain (primary).

1.3 APPLICATION

More effective and efficient management of:

1) Reservoir levels,
2) Hazard warning,
3) Ship routing, and
4) Water and weather forecasting.

1.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Coverage requirements include worldwide estuarine areas for estuarine sea state measurements, worldwide land masses for snow morphology measurements, worldwide lake and sea ice morphology measurements above 50°N and below 50°S latitudes, and global areas for rain measurements.

1.5 SENSCR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Estuarine Sea State**

Range:	0-30 m/sec
Accuracy:	1.5 m/sec
Sensitivity:	1.0 K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	0.066 seconds
Bandwidth:	90 MHz
Sensor Interference Threshold:	-156 dBW
Competing Effects:	Rain, Clouds

- **Lake Ice Morphology**

Sensitivity:	1.0 K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	60-100 milliseconds
Bandwidth:	90 MHz
Sensor Interference Threshold:	-156 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain, and Clouds (19.9, 37.0 GHz) and Snow Cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz)

- Snow Morphology

Range:	0-20% free water content
Accuracy:	2%
Sensitivity:	1.0 K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	0.066 seconds
Bandwidth:	90 MHz
Sensor Interference Threshold:	-156 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain and Clouds (19.9, 37.0 GHz)

- Sea Ice Morphology

Range:	Location and Type
Sensitivity:	1.0 K
Resolution (swath):	20 km (800 km)
Update Rate:	1 per day
Integration Time:	0.05 seconds
Bandwidth:	120 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Rain (19.9, 37.0 GHz) and Snow Cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz)

- **Rain**

Range:	0-100 mm/hr
Accuracy:	20%
Sensitivity:	1.0 K
Resolution:	1 km (limited)
Update Rate:	1 per day
Integration Time:	0.05 secondsseconds
Bandwidth:	120 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow (1.4, 2.7, 10.7, 19.9, 37.0 GHz), Lake ice (10.7, 19.9, 37.0 GHz), Sea state (10.7, 19.9 GHz) Surface temperature (5.0 GHz) and Limited Dynamic Range (1)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	15 meter (1 km resolution)

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(1) Radiometric measurements at a single frequency have a limited dynamic range. To extend the dynamic range simultaneous measurements must be made at a number of frequencies between 6 and 37 GHz. If overland measurements are to be made, observations should be made at even lower frequencies.

- Operational Requirements

The data requirements for applications in this band is once per day. Continuous spacecraft measurements over applicable areas are required to compile this data.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., rain, clouds, soil moisture, water vapor, snow, lake ice, sea state, surface temperature, etc.).

1.6 STATUS OF TECHNOLOGY AND USE

Current development and testing is proceeding on the Scanning Multichannel Microwave Radiometer Simulator and the Passive Microwave Imaging System. The Scanning Multichannel Microwave Radiometer will be flown on Nimbus-G (1978) and Seasat-A (1977) while the Low-Noise Microwave Radiometer and Shuttle Imaging Microwave System will be flown on the Shuttle. Operational use is expected in the mid-1980's on the Shuttle, Landsat and Seasat follow-on missions.

1.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

Use of the band 10.6 to 10.7 GHz is optimum for the measurement of sea state, ice and snow characteristics over small surface areas without being significantly affected by atmospheric water vapor.

This band is also optimum for the measurement of high rain rates over small spatial resolution elements. High rain rates cause higher frequency measurements of liquid water to be weighted toward the top of the atmosphere. High rain rates, in the lower layers of the atmosphere, can be measured in the 10.6 to 10.7 GHz band.

The required bandwidth (100 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the required bandwidth is contained in Chapter II, Part B, Section 1.

1.8 SHARING ANALYSIS RESULTS

Portions of the 10.6-10.7 GHz frequency band are currently allocated to the Fixed and Mobile Services (10.6-10.68 GHz) and the Radio Astronomy Service (10.68-10.70 GHz) on a primary basis worldwide.

The sharing analysis results, presented in Table 1-1, are based on information contained in the United States and international frequency assignment data files. The detailed sharing analysis can be found in Chapter II, Part B, Section 1.

It was found that present use of the 10.6-10.68 GHz band by the Fixed and Mobile Services is sparse, and, in general, low power systems are being utilized. Sharing on a simultaneous operation basis with current assignments in the band is considered feasible.

1.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Fixed and Mobile Service in the 10.6-10.7 GHz region is feasible. Consequently, the space passive services can share on a primary, co-equal basis with the Fixed and Mobile Services. The following footnote should be included:

> "Fixed and Mobile systems operating in the 10.6-10.7 GHz portion of the 10.6-10.95 GHz Fixed and Mobile allocation, are limited to 1 to 2 watt transmitter powers. Fixed and Mobile systems with higher powers must use the 10.7-10.95 GHz portion of the allocation."

Table 1-1

SUMMARY OF SHARING ANALYSES RESULTS

		FIXED AND MOBILE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) IN THE MAIN BEAM OF ONE INTERFEROR		-1
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-44
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	(km^2)	---
	%**	---
SIMULTANEOUS SHARING FEASIBLE		YES

* (-) Indicates Below Interference Threshold of -156 dB(W).

** Percentage number is percent of area lost to the radiometer when in view of the interferor.

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SECTION 2

FREQUENCY BAND 15.3 - 15.5 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

15.3-15.5 GHz BAND

2.1 ALLOCATIONS

The existing allocations and proposed changes in the 15.3-15.5 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
14.5-15.35 GHz	FIXED MOBILE (Technical Feasibility of sharing with Space Research still under study) 408B 408C	
15.35-15.4	RADIO ASTRONOMY EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) ~~409C~~	
15.4-15.7	NOC	
	NON-GOVERNMENT	
15.3-15.4	RADIO ASTRONOMY 409C	
15.4-~~15.70~~ 15.55	RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION 352A 352B 407	

2.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary)
2) Rain (primary)
3) Soil moisture (secondary)
4) Snow morphology (secondary)
5) Lake ice (secondary)
6) Estuary sea state (secondary)
7) Ocean sea state (secondary), and
8) Ocean ice morphology (secondary).

2.3 APPLICATION

More effective and efficient management of:

1) Water resources
2) Weather and climate forecasting
3) Short range forecasting, and
4) Long range and climatological forecasting.

2.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Surveillance of all areas on a global basis is necessary for rain and water vapor measurements.

2.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Water vapor**

Range:	0-7 gm/cm^2 [1]
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.2 K
Resolution:	2.0 km [2]
Update Rate:	2 per day
Integration Time:	0.2 seconds
Bandwidth:	180 MHz
Sensor Interference Threshold:	-160 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow morphology (1.4, 2.7, 10.7, 19.9, 37 GHz), Lake ice (10.7, 19.9, 37 GHz), sea state (10.7, 19.9 GHz), sea ice (1.4, 10.7, 19.9 GHz), clouds (37, 90 GHz), rain (19.9, 37 GHz), atmospheric temperature (52 GHz)

- **Rain**

Range:	0-100 mm/hr.
Accuracy:	20%
Sensitivity:	1.0 K
Resolution (swath):	1 km (limited)
Update Rate:	1 per day
Integration Time:	0.008 seconds

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(1) Total Precipitable Water.

(2) 2 km over land, 20 km over oceans.

- **Rain (cont.)**

Bandwidth:	195 MHz
Sensor Interference Threshold:	-153 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow (1.4, 2.7, 10.7, 19.9, 37 GHz), Lake ice (10.7, 19.9, 37 GHz), Sea state (10.7, 19.9 GHz), Surface temperature (5.0 GHz), and Limited Dynamic Range[1]

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	5 meter (2 km resolution)

- **Operational Requirements**

Rain and water vapor profiles are required at least once per day. Continuous spacecraft measurements are required to compile these profiles.

(1) Radiometric measurements at a single frequency have a limited dynamic range. To extend the dynamic range, simultaneous measurements must be made at a number of frequencies between 6 and 37 GHz. If measurements over land are to be made, observations should be made at even lower frequencies.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., surface temperature, sea state, soil moisture, snow, lake ice, sea ice, clouds, atmospheric temperature, etc.).

2.6 STATUS OF TECHNOLOGY AND USE

Studies are continuing in the development of future instruments to be used in this band. Operational use of this band is expected in the mid-80's on the space shuttle and on meteorological satellites.

2.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required to:

1) extend the dynamic range for rain measurements in the lower layers of the atmosphere, and

2) to provide water vapor information in the lowest layer of the atmosphere.

This frequency is the lowest possible for successfully detecting water vapor.

This band provides rain data at intermediate rain rates.

The required bandwidth (180 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 2.

2.8 SHARING ANALYSIS RESULTS

Portions of the 15.3 to 15.5 GHz spectral region are currently allocated to the Fixed, Mobile, Aeronautical Radionavigation, and Radio Astronomy Services.

The sharing analyses results are based on national, as well as international, frequency assignment data files and, in some cases, anticipated future use of the band.

The results are based on the following underlying assumptions:

- Fixed and Mobile Services will employ FDM-FM transmission techniques;
- The Aeronautical Radionavigation allocation will be used for Microwave Landing Systems of both high and low power transmissions.

The results of the analyses are presented below and in Table 2-1. The detailed analyses can be found in Chapter II. Part B, Section 2.

Table 2-1

SUMMARY OF SHARING ANALYSES RESULTS

		AERONAUTICAL RADIONAVIGATION	FIXED AND MOBILE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR		+32	+14
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-16	-30
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	$2.5x10^6$	$1.6x10^5$
	%**	14%	1%
SIMULTANEOUS SHARING FEASIBLE		NO	NO
TIME SHARING FEASIBLE		NO	NO

*(-) Indicate below interference threshold of -160 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of the interferor.

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- Fixed and Mobile Services

  - Harmful interference, on a simultaneous operational basis, will be encountered with low numbers of transmitters (25-100) located in view of the radiometer. Since developed countries, in particular, are expected to utilize this band, densities are likely to be such that large geographical areas, around the developed countries, will experience harmful interference.

  - Time sharing is generally infeasible with Fixed and Mobile Services.

- Aeronautical Radionavigation

  - Harmful interference, on a simultaneous operational basis, will be encountered with large numbers of low power MLS transmitters (300-500) in view of the radiometer. Although there are some indications that worldwide MLS systems will operate lower in the spect (5.000-5.250 GHz), if they are implemented at 15 GHz, their densities, at least in developed countries, will be such that harmful interference will be encountered around the countries concerned.

  - Time sharing is infeasible with MLS systems.

2.9 SHARING CONSIDERATIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors of the Earth Exploration Satellite or Space Research Services, and the Fixed and Mobile (15.3-15.35 GHz) and the Aeronautical Radionaviagtion (15.4-15.5 GHz) Services in the 15.3-15.5 GHz region, is not feasible. Time sharing is generally infeasible with Fixed and Mobile Services, while definitely infeasible with Aeronautical Radionavigation.

Sharing on a simultaneous operational basis between the space passive services and the Radio Astronomy Service in the 15.35-15.4 GHz band is feasible.

SECTION 3

FREQUENCY BAND 17.7 - 17.9 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

17.7-17.9 GHz BAND

3.1 ALLOCATIONS

The existing allocations and proposed changes in the 17.7-17.9 GHz frequency band are given below for Regions 1, 2 and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
17.7-17.9	~~FIXED~~ FIXED-SATELLITE (Space-to-Earth) ~~MOBILE~~ EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive)	
	NON-GOVERNMENT	
17.7-19.7 NOC	FIXED FIXED-SATELLITE (Space-to-Earth) MOBILE	

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3.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary)
2) Soil moisture content (secondary)
3) Snow morphology (secondary)
4) Lake ice (secondary)
5) Estuarine sea state (secondary)
6) Ocean sea state (secondary)
7) Ice morphology (secondary), and
8) Rain (secondary)

3.3 APPLICATION

More effective and efficient management of:

1) Short range forecasting and,
2) Long range and climatological forecasting

3.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Water vapor measurements are required on a global basis.

3.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Water Vapor**

Range:	0-7 gm/cm^2 (1)
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.2 K
Resolution:	2 km (2)
Update Rate:	2 per day
Integration Time:	0.2 sec.
Bandwidth:	180 MHz
Sensor Interference Threshold:	-160 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow morphology (1.4, 2.7, 10.7, 19.9, 37 GHz), Lake ice (10.7, 19.9, 37 GHz), Sea state (10.7, 19.9 GHz), Sea ice (1.4, 10.7, 19.9 GHz), Clouds (37, 90 GHz), Rain (19.9, 37 GHz), and Atmospheric temperature (52 GHz).

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-100° (for world-wide coverage)
Antenna:	5 meter

(1) Total Precipitable Water

(2) 2 km over land, 20 km over ocean

- <u>Operational Requirements</u>

Water vapor profiles are required twice per day. Continuous spacecraft measurements are required to compile these profiles.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., soil moisture, snow morphology, lake ice, sea state, sea ice, clouds, rain, atmospheric, temperature, etc.).

3.6 STATUS OF TECHNOLOGY AND USE

The Scanning Multichannel Microwave Radiometer is being developed for the Nimbus-G (1978) and SEASAT-A (1977). Operational use is expected in the mid 1980's for the Shuttle, meteorological satellites, and SEASAT follow-on missions.

3.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This frequency is required in order to determine water vapor content at intermediate heights in the lower atmosphere.

The required bandwidth (200 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 3.

3.8 SHARING ANALYSIS RESULTS

Portions of the 17.7 to 17.9 GHz spectral region are currently allocated to the Fixed, Mobile, and Fixed Satellite (space-to-earth) Services. In the United States, deletion of Government sector Fixed and Mobile Services is proposed.

The results presented are based on national as well as international frequency assignment data files, and an assessment of anticipated future use of the band.

The assumptions underlying these analyses are that:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Transmitters will be located in highly populated, economically developed areas and would employ 10 km hops.

- Fixed-Satellite use in the United States, and elsewhere, will be primarily by common carriers or national P.T.T. agencies, and will be full-time in nature.

The results of the sharing analyses are presented below and are summarized in Table 3-1. The detailed sharing analyses can be found in Chapter II, Part B, Section 3.

- Fixed and Mobile Service

  - No harmful interference to the passive services will result from simultaneous operation of Fixed and Mobile Service transmitters.

- Fixed-Satellite Service

  - Harmful interference on a simultaneous operational basis will be encountered in the large areas of the world which will be served by satellites in this service.

  - Time sharing is not feasible because of the full-time nature of the Services.

Table 3-1

SUMMARY OF SHARING ANALYSIS RESULTS

	FIXED & MOBILE SERVICES	FIXED SATELLITE SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR	-21	+27
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR	-75	-32
LOSS OF COVERAGE AREA (km^2)	---	4.3×10^6
%**	---	1.7%
SIMULTANEOUS SHARING FEASIBLE	YES	NO
TIME SHARING	---	NO

* (-) Indicates below interference threshold of -160 dB(W).

** Percentage number is percent of area lost to the radiometer when in view of a fixed satellite.

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3.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Fixed and Mobile Services in the 17.7 to 17.9 GHz band is feasible.

Sharing on a simultaenous operational basis between spaceborne microwave sensors and the Fixed-Satellite Service is infeasible. Time sharing with this service does not seem to be a viable alternative.

SECTION 4

FREQUENCY BAND 19.7 - 19.9 GHz

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 19.7-19.9 GHz BAND

4.1 ALLOCATIONS

The existing allocations and proposed changes in the 19.7-19.9 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
19.7-19.9	FIXED-SATELLITE (Space-to-Earth) EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) 409E	

Region 1	Region 2	Region 3
	NON-GOVERNMENT	
NOC 19.7-21.2	FIXED-SATELLITE (Space-to-Earth) 409E	

4.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary)
2) Snow morphology (primary)
3) Lake ice (primary)
4) Estuarine Sea State (primary)
5) Ocean Sea State (primary)
6) Ocean Ice Morphology (primary)
7) Rain (primary)
8) Estuarine Oil Slick (secondary)
9) Ocean Oil Slick (secondary).

4.3 APPLICATION

More effective and efficient management of:

1) climatological forecasting,
2) streamflow forecasting,
3) shipping season,
4) hazardous situation warning,
5) ship routing and scheduling, and
6) water.

4.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Coverage requirements include worldwide estuarine areas for estuarine sea state measurements, worldwide land masses for snow morphology measurements, worldwide lake, and sea ice morphology measurements above 50°N and below 50°S latitudes, and global areas for rain and water vapor measurements.

4.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- Water Vapor

Range:	0-7 gm/cm^2 (1)
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.2 K
Resolution:	2 km (2)
Update Rate:	2 per day
Integration Time	0.2 seconds
Bandwidth:	180 MHz
Sensor Interference Threshold:	-160 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow morphology (1.4, 2.7, 10.7, 19.9, 37 GHz), Lake ice (10.7, 19.9, 37 CHz), Sea state 10.7, 19.9 GHz), Sea ice (1.4, 10.7, 19.9 GHz), Clouds (37, 90 GHz), Rain (19.9, 37 GHz), and Atmospheric temperature (52 GHz).

(1) Total Precipitable Water

(2) 2 km over land, 20 km over ocean

- <u>Snow Morphology</u>

Range:	0-20% free water content
Accuracy:	2%
Sensitivity:	1.0 K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	0.03 seconds
Bandwidth:	210 MHz
Sensor Interference Threshold:	-152 dB(W)
Competing Effects:	Water vapor (22.4 GHz Rain and Clouds (19.9, 37.0 GHz)

- <u>Lake Ice Morphology</u>

Sensitivity:	1.0K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	0.03 seconds
Bandwidth:	200 MHz
Sensor Interference Threshold:	-152 dB(W)
Competing Effects:	Water vapor (22.4 GHz Rain, and Clouds (19.9, 37.0 GHz) and Snow Cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz)

- <u>Estuarine Sea State</u>

Range:	0-30 m/sec
Accuracy:	2 m/sec
Sensitivity:	1.0 K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	.03 seconds
Bandwidth:	210 MHz
Sensor Interference Threshold:	-152 dB(W)
Competing Effects:	Rain, Clouds (19.9, 37 GHz)

- <u>Ocean Sea State</u>

Range:	0-40 m/sec
Accuracy:	2 m/sec
Sensitivity:	1.0 K
Resolution (swath):	20 km (800 km)
Update Rate:	1 per day
Integration Time:	0.05 seconds
Bandwidth:	120 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Rain, (19.9, 37.0 GHz)

- <u>Ocean Ice Morphology</u>

Range:	Location and Type
Sensitivity:	1.0 K
Resolution (swath):	2-20 km
Update Rate:	1 per day
Integration Time:	0.05 seconds
Bandwidth:	120 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Rain (19.9, 37.0 GHz) and Snow Cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz)

- <u>Rain</u>

Range:	0-100 mm/hr
Accuracy:	20%
Sensitivity:	1.0 K
Resolution (swath):	1 km
Update Rate:	1 per day
Integration Time:	0.033 seconds
Bandwidth:	180 MHz
Sensor Interference Threshold:	-153 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow (1.4, 2.7, 10.7, 19.9, 37.0 GHz Lake ice (10.7, 19.9, 37.0 GHz), Sea state (10.7, 19.9 GHz) Surface temperature (5.0 GHz) and Limited Dynamic Range (1)

(1) Radiometric measurements at a single frequency have a limited dynamic range. To extend the dynamic range simultaneous measurements must be made at a number of frequencies between 6 and 37 GHz. If overland measurements are to be made, observations should be made at even lower frequencies.

- <u>Spacecraft Parameters</u>

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	5 meter (2 km resolution)

- <u>Operational Requirements</u>

Water vapor and rain profiles are required at least once per day. Other measurements are required once per day. Continuous spacecraft measurements are required to compile this data.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., soil moisture, snow morphology, lake ice, sea state, sea ice, clouds, rain, atmospheric, temperature, etc.).

4.6 STATUS OF TECHNOLOGY AND USE

The Electronically Scanning Microwave Radiometer has been developed and flown on Nimbus-5. Current development and testing are proceeding on the Shuttle Imaging Microwave System, and the Rain Mapping Radiometer for use on the meteorological-satellites. Operational use will continue in the mid-1980's, for both the Shuttle and meteorological satellites.

4.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This frequency is required in order to determine water vapor content at high heights in the atmosphere.

This band is also useful for the detection of water content in snow, the measurement of ice thickness and the detection of water layers on ice.

This band is sensitive to rain at lower rain rates and provides a good compromise for a single observing frequency when used with a large spatial resolution element, 20 km or more, averaged over the higher rain rates.

This band also maximizes sensitivity to sea state while minimizing the effects of clouds.

Measurements in this band are made in conjunction with measurements in other bands for each of the applications.

The required bandwidth (180 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 4.

4.8 SHARING ANALYSIS RESULTS

The 19.7-19.9 GHz band is currently allocated to the Fixed-Satellite Service on a worldwide basis. This allocation is restricted to the space-to-earth direction. In addition, Footnote 409E indicates that the band may be used for Fixed and Mobile operations in Japan.

The results presented are based on national as well as international frequency assignment data files, and an assessment of anticipated future use of the band.

The assumptions underlying these analyses are that:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Transmitters would be located in Japan and would employ 10 km hops.
- Fixed-Satellite use in the United States, and elsewhere, will be primarily by common carriers or national P.T.T. agencies, and will be full-time in nature.

The results of the sharing analyses are presented below. The detailed sharing analyses can be found in Chapter II, Part B, Section 4.

The results are summarized in Table 4-1.

TABLE 4-1

SUMMARY OF SHARING ANALYSIS RESULTS

	FIXED & MOBILE SERVICES	FIXED SATELLITE SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR	-31.4	+26
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR	-85.4	-25
LOSS OF COVERAGE AREA (km^2)	---	3.7×10^6
%**	---	1.5 %
SIMULTANEOUS SHARING FEASIBLE	YES	NO
TIME SHARING	---	NO

* (-) Indicates below interference threshold of -160 dB(W).

** Percentage number is percent of area lost to the radiometer when in view of a fixed satellite.

- Fixed and Mobile Service

  - No harmful interference to the passive services will result from simultaneous operation of Fixed and Mobile Service transmitters.

- Fixed-Satellite Service

  - Harmful interference on a simultaneous operational basis will be encountered in large areas of the world served by satellites in this service.

  - Time sharing is not feasible because of the full-time nature of the Services.

4.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne microwave sensors and the Fixed and Mobile Services in the 19.7 to 19.9 GHz band is feasible.

Sharing on a simultaneous operational basis between spaceborne microwave sensors and the Fixed-Satellite Service is infeasible. Time sharing with this service [illegible] a viable alternative.

SECTION 5

FREQUENCY BAND 21.0 - 21.2 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

21.0-21.2 GHz BAND

5.1 ALLOCATIONS

The existing allocations and proposed changes in the 21.0-21.2 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

REGION 1	REGION 2	REGION 3
	GOVERNMENT	
19.9-21.2	FIXED-SATELLITE (Space-to-Earth) MOBILE SATELLITE (Space-to-Earth) 409E	

MOD 409E In Japan the bands 19.7-21.2 GHz and 29.5-31 GHz are also allocated to the Fixed and Mobile Services. This additional use shall not impose any limitations on the power flux density of space stations in the Fixed-Satellite or Mobile-Satellite Services.

	NON-GOVERNMENT	
19.7-21.2 NOC	FIXED SATELLITE (Space-to-Earth) 409E	

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5.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary), and

2) Rain (secondary)

5.3 APPLICATION

More effective and efficient management of:

1) Water

2) Short range forecasting, and

3) Long range and climatological forecasting

5.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

These include global areas for water vapor measurements.

5.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- Water Vapor

Range:	0-7 gm/cm^2 (1)
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.2 K
Resolution:	2 km(2)
Update Rate:	2 per day

(1) Total precipitable water

(2) 2 km over land, 20 km over ocean

Water Vapor (cont)

Integration Time:	0.2 seconds
Bandwidth:	180 MHz
Sensor Interference Threshold:	-160 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), snow morphology (1.4, 2.7, 10.7, 19.9, 37 GHz), lake ice (10.7, 19.9, 37 GHz), sea state (10.7, 19.9 GHz), sea ice (1.4, 10.7, 19.9 GHz) clouds (37, 90 GHz), rain (19.9, 37 GHz) and atmospheric temperature (52 GHz)

- Spacecraft Parameters

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	4 meter diameter

- Operational Requirements

Water vapor profiles are required twice per day. Continuous spacecraft measurements are required to compile these profiles.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., soil moisture, snow morphology, lake ice, sea state, sea ice, clouds, rain, atmospheric temperature, etc.).

5.6 STATUS OF TECHNOLOGY AND USE

Current development and flight testing is in progress on the Scanning Multichannel Microwave Radiometer (SMMR) for Nimbus-G (1978), and Seasat-A (1977). The Low-Noise Microwave Radiometer, an advanced SMMR, is planned for the Shuttle. Operational use is expected in the mid-1980's, on the Shuttle meteorological satellites and Seasat follow-on missions.

5.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for water vapor measurements in a higher intermediate layer of the atmosphere.

The required bandwidth (180 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 5.

5.8 SHARING ANALYSIS RESULTS

Portions of the 21.0 to 21.2 GHz spectral region are currently allocated to the Fixed-Satellite (space-to-earth) Service. Additional allocations are currently being proposed to add the Mobile-Satellite Service to the 20.2-21.2 GHz band.

The following are the assumptions underlying the analysis:

- Use of the band will be primarily for military communication world-wide.

- The down-link transmission will employ spread spectrum techniques in order to obtain secure communications.

The results of the analysis are presented below and are summarized in Table 5-1. The detailed analysis can be found in Chapter II, Part B, Section 5.

- Due to the spread-spectrum techniques expected to be employed in government communication systems, sharing on a simultaneous operations basis appears feasible.

5.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and Fixed and Mobile-Satellite Services (down-link) is considered feasible.

Consequently, a primary, co-equal allocation between these services is feasible. The criteria for the passive services to share with Fixed and Mobile-Satellites is that the Fixed and Mobile-Satellites do not exceed a PFD at the surface of the earth of -155 dB(W/m^2/4 kHz), or equivalently a -29 dB(W/Hz) e.i.r.p.

TABLE 5-1

SUMMARY OF SHARING ANALYSIS RESULTS

		FIXED- and MOBILE-SATELLITE (space-to-earth)
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-3**
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-46
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	(km^2)	---
	%	---
SIMULTANEOUS SHARING FEASIBLE		YES
TIME SHARING FEASIBLE		---

* (-) Indicates below interference threshold of -160 dB(W).

** Assuming use of spread spectrum techniques.

SECTION 6

FREQUENCY BAND 22.1 - 22.5 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

22.1-22.5 GHz BAND

6.1 ALLOCATIONS

The existing allocations and proposed changes in the 22.1-22.5 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
22.1-22.5	~~FIXED~~ ~~MOBILE~~ EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) RADIO ASTRONOMY ~~410A~~	
SUP 410A		
	NON-GOVERNMENT	
22 - ~~22.5~~ 22.21	FIXED MOBILE ~~410A~~	
22.21-22.26	FIXED MOBILE (except Aeronautical Mobile) RADIO ASTRONOMY ~~410A~~	

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<u>22.26</u>-<u>22.3</u>	FIXED ~~MOBILE~~ ~~410A~~
<u>22.3</u>-22.5	FIXED ~~MOBILE~~ <u>GENERAL RADIO SERVICE</u> ~~410A~~

6.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary)

6.3 APPLICATION

More effective and efficient management of:

1) Short range forecasting, and

2) Long range and climatological forecasting

3) Water vapor data for correction of measurements for most microwave sensing applications

6.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Global geographical coverage is required for water vapor measurements.

6.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Water Vapor**

Range:	0-7 gm/cm^2 (1)
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.4 K
Resolution (swath):	2 km(2) (limited)
Update Rate:	2 per day
Integration Time:	0.022 seconds
Bandwidth:	405 MHz
Sensor Interference Threshold:	-153 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), snow morphology (1.4, 2.7, 10.7, 19.9, 37 GHz), lake ice (10.7, 19.9, 37 GHz) sea state (10.7, 19.9 GHz), sea ice (1.4, 10.7, 19.9 GHz), clouds (37, 90 GHz), rain (19.9, 37 GHz) and atmospheric temperature (52 GHz)

(1) Total precipitable water.

(2) 2 km over land, 20 km over ocean.

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	4 meter

- **Operational Requirements**

Water vapor profiles are required twice per day. Continuous spacecraft measurements are required to compile these profiles. This measurement is also needed simultaneously with other microwave sensing measurements as a correction factor.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminat competing effects (i.e., soil moisture, soil mc logy, lake ice, sea state, sea ice, clouds, rain, atmospheric temperature, etc.).

6.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are in progress on the Shuttle Imaging Microwave System for the Shuttle, and the Scanning Microwave Spectrometer for Nimbus G (1978) and SEASAT-A (1977). The Nimbus-E Microwave Spectrometer is presently in orbit and the Passive Microwave Imaging System has flown aboard aircraft.

Work is also continuing on the Storm Structure Microwave Spectrometer. Operational use is expected in the mid-1980's for the Shuttle, meteorological satellites, LANDSAT and Seasat follow-on missions.

6.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for water vapor profile measurement and for the measurement of total precipitable water in the atmosphere.

This frequency is uniquely determined by the molecular H_2O resonance frequency at 22.235 GHz.

The required bandwidth (400 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration times, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 6.

6.8 SHARING ANALYSIS RESULTS

Portions of the 22.1 to 22.5 GHz spectral region are currently allocated to the Fixed and Mobile Services, with a proposed addition by the FCC for General Radio Services (citizen's band). A sharing analysis of citizen's band operations was not performed since it is not probable that technology will permit the competitive use of this band for this purpose within the next 20 years.

The following assumptions underline the sharing analysis:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Transmitters will be located primarily on land and in highly populated, economically developed areas and would employ 10 km hops.

The results are summarized below and in Table 6-1. The detailed analysis can be found in Chapter II, Part B, Section 6.

- Harmful interference on a simultaneous operational basis will not occur to passive remote sensors. The number of systems required to cause interference is very much greater than any projected use of the band.

6.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and Fixed and Mobile Services is feasible due to the low required e.i.r.p. of digitally encoded fixed and mobile systems in the 22.1-22.5 GHz band.

Consequently, a primary, co-equal allocation between the space passive services and the Fixed and Mobile Services is feasible. The criteria for sharing with digital fixed and mobile systems is that these systems conform to the specifications of CCIR Reports 387-2, 609, and 610.

TABLE 6-1

SUMMARY OF SHARING ANALYSIS RESULTS

		FIXED & MOBILE
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-50
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-103
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	----
	%	----
SIMULTANEOUS SHARING FEASIBLE		YES

* (-) Indicates below interference threshold of -157 dB(W).

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SECTION 7

FREQUENCY BAND 23.6 - 24.0 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

23.6-24.0 GHz BAND

7.1 ALLOCATIONS

The existing allocations and proposed changes in the 23.6-24.0 GHz frequency band are given below for Regions 1, 2 and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
23.6-24.0	RADIO ASTRONOMY SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) ~~407~~	
SUP 407		
	NON-GOVERNMENT	
23.6-24.0 NOC	RADIO ASTRONOMY MOD 407	

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7.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary), and

2) Rain (secondary).

7.3 APPLICATION

More effective and efficient management of:

1) Water

2) Short range forecasting, and

3) Long range and climatological forecasting

7.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Geographical coverage requirements include global areas for water vapor measurements.

7.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- Water Vapor

Range:	0-7 gm/cm^2 (1)
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.2 K
Resolution:	2 km (2)
Update Rate:	2 per day

---

(1) Total Precipitable Water

(2) 2 km over land, 20 km over ocean.

Water Vapor (cont)

Integration Time:	0.2 seconds
Bandwidth:	180 MHz
Sensor Interference Threshold:	-160 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), snow morphology (1.4, 2.7, 10.7, 19.9, 37 GHz) lake ice (10.7, 19.9, 37 GHz), sea state (10.7, 19.9 GHz), sea ice (1.4, 10.7, 19.9 GHz) clouds (37, 90 GHz), rain (19.9, 37 GHz) and atmospheric temperature (52 GHz)

- Spacecraft Parameters

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	4 meter

- Operational Requirements

Water vapor profiles are required twice per day. Continuous spacecraft measurements are required to compile these profiles.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., soil moisture, snow morphology, lake ice, sea state, sea ice, clouds, rain, atmospheric temperature, etc.).

7.6 STATUS OF TECHNOLOGY AND USE

Studies are continuing in the development of future instruments to be used in this band. Operational use is expected in the mid-1980's for the Shuttle and meteorological satellites.

7.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for water vapor measurements in an intermediate layer of the atmosphere on the wing of the H_2O line at 22.235 GHz.

The required bandwidth (180 MHz) is determined by the radiometer sensitivity, integration time and receiver noise temperature, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 7.

7.8 SHARING ANALYSIS RESULTS

The 23.6 to 24.0 GHz spectral region is currently allocated to the Radio Astronomy Service. It is proposed that this band be shared with Space Research (passive). Since the Radio Astronomy and Space Research (passive) Services can inherently share with another passive service, frequency sharing in the 23.6-24.0 GHz band is feasible.

7.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Radio Astronomy Services is feasible.

Consequently, a primary, co-equal allocation is feasible.

SECTION 8

FREQUENCY BAND 31.3 - 31.8 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

31.3-31.8 GHz BAND

8.1 ALLOCATIONS

The existing allocations and proposed changes in the 31.3-31.8 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
31.3-31.5	RADIO ASTRONOMY SPACE RESEARCH (Passive Sensor) EARTH EXPLORATION SATELLITE (Passive Sensor) ~~412A~~	
31.5-31.8 SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) RADIO ASTRONOMY Fixed Mobile (except aeronautical mobile)	SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) RADIO ASTRONOMY Fixed Mobile (except aeronautical mobile)	SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) RADIO ASTRONOMY Fixed Mobile (except aeronautical mobile) 405C
	NON-GOVERNMENT	
31.3-31.5	RADIO ASTRONOMY ~~412A~~	

31.5-31.8		
SPACE RESEARCH ~~Fixed~~ ~~Mobile~~ RADIO ASTRONOMY	SPACE RESEARCH RADIO ASTRONOMY 405C	SPACE RESEARCH ~~Fixed~~ ~~Mobile~~ RADIO ASTRONOMY

8.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Water vapor (primary)
2) Snow morphology
3) Ice morphology

8.3 APPLICATION

More effective and efficient management of:

1) Water
2) Short range forecasting
3) Long range and climatological forecasting
4) Ship routing

8.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Coverage requirements include worldwide snow and ice areas, primarily above 30°N and below 30°S, and global areas for water vapor.

8.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Water Vapor**

Range:	0-7 gm/cm^2 (1)
Accuracy:	0.3 gm/cm^2
Sensitivity:	0.2 K
Resolution:	2 km (2)
Update Rate:	2 per day
Integration Time:	0.2 seconds
Bandwidth:	180 MHz
Sensor Interference Threshold:	-160 dB(W)
Competing Effects:	Soil Moisture (1.4, 2.7 GHz) Snow Morphology (1.4, 2.7, 10.7, 19.9, 37.0 GHz) Sea state (10.7, 19.9 GHz) Sea ice (1.4, 10.7, 19.9 GHz) Clouds (37, 90 GHz) Rain (19.9, 37.0 GHz) Atmospheric temperature (52 GHz)

- **Sea Ice Morphology**

Range:	Location and Type
Sensitivity:	1.0 K
Resolution (swath):	20 km (800 km)
Update Rate:	1 per day
Integration Time:	2.0 seconds

(1) Total precipitable water

(2) 2 km over land, 20 km over water

Bandwidth:	120 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Rain (19.9, 37.0 GHz) and Snow Cover (10.7, 19.9, 37.0 GHz)

- Snow Morphology

Range:	0-20% free water content
Accuracy:	2%
Sensitivity:	1.0 K
Resolution (swath):	2-5 km (limited)
Update Rate:	1 per day
Integration Time:	0.066 seconds
Bandwidth:	90 MHz
Sensor Interference Threshold:	-156 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain and Clouds (19.9, 37.0 GHz)

- Spacecraft Parameters

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	2 meter (2 km resolution)

- Operational Requirements

Water vapor profiles are required twice per day, while surface phenomena data are required once per day. Continuous spacecraft measurements are required to compile these profiles.

Data acquired in this frequency band must be used in conjunction with measurements in other bands to eliminate competing effects.

8.6 STATUS OF TECHNOLOGY AND USE

The Scanning Microwave Spectrometer has been developed and is operating on Nimbus-6. Current development and testing are proceeding on the Storm Structure Microwave Spectrometer for use on meteorological-satellites. Operational use will continue in the mid-1980's on meteorological satellites.

8.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for water vapor measurements in an intermediate layer of the atmosphere due to its proximity to the 22.235 GHz water vapor rotational line. Also this band is below the oxygen high attenuation rotation lines in the 50-70 GHz region, yet above the water vapor line. Consequently, this band is useful for sensing surface phenomena.

The required bandwidth (180 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 8.

8.8 SHARING ANALYSIS RESULTS

The 31.3-31.5 GHz band is currently allocated to the Radio Astronomy Services in Region 1, 2, and 3. However, Footnote 412A specifies that in Bulgaria, Cuba, Hungary, Poland, Czechoslovakia and the U.S.S.R., the band is also allocated to the Fixed and Mobile Services. The 31.5-31.8 GHz band is allocated on a primary basis to Space Research and on secondary basis to the Fixed and Mobile Services.

Since passive spaceborne sensors can inherently share with the Radio Astronomy Service, this analysis is concerned only with the Fixed and Mobile Services in the above mentioned countries.

The results presented herein are based on national as well as international frequency assignment data files and anticipated future use of the band. The assumptions underlying this analysis are that

- The fixed and mobile systems in this band will be located primarily on land in highly populated, economically developed areas.

- Systems will be digitally encoded rather than analog, and system hop lengths of 10 km will be typical.

The results of the sharing analysis are presented below as well as in Table 8-1. The detailed analysis can be found in Chapter II, Part B, Section 8.

- Fixed and Mobile Services

  - Harmful interference during simultaneous operations will not be encountered due to the low e.i.r.p. envisioned to be used by Fixed and Mobile systems at 31.3-31.5 GHz.

TABLE 8-1

SUMMARY OF SHARING ANALYSES RESULTS

		FIXED AND MOBILE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-28
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-76
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	(km^2)	—
	%	—
SIMULTANEOUS SHARING FEASIBLE		YES

* (-) Indicates below interference threshold of -160 dB(W).

8.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Fixed and Mobile Services in the 31.3-31.8 GHz band is feasible.

Consequently, a primary co-equal allocation is feasible. The criterion for the spaceborne passive services to share with the Fixed and Mobile Services is that fixed and mobile emissions conform to the general guidelines of CCIR Reports 387-2, 609, and 610.

SECTION 9

FREQUENCY BAND 36.0 - 37.0 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

36.0-37.0 GHz BAND

9.1 ALLOCATIONS

The existing allocations and proposed changes in the 36.0-37.0 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
GOVERNMENT		
36-37	~~FIXED~~ ~~MOBILE~~ SPACE RESEARCH (Passive) EARTH EXPLCRATION SATELLITE (Passive) FIXED-SATELLITE MOBILE-SATELLITE 391A 412E	
NON-GOVERNMENT		
36-40	FIXED MOBILE 391A 412E	

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9.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Rain (primary)
2) Snow morphology (primary)
3) Lake ice (primary)
4) Estuarine oil slick (primary)
5) Ocean ice morphology (primary)
6) Ocean oil slick (primary)
7) Estuarine sea state (secondary)
8) Ocean sea state (secondary), and
9) Clouds (secondary).

9.3 APPLICATION

More effective and efficient management of:

1) Streamflow forecasting
2) Transport
3) Environmental regulations
4) Ship routing and scheduling
5) Pollution
6) Water, and
7) Weather forecasting.

9.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Geographical coverage requirements include worldwide estuarine, lake, coastal and open ocean areas for estuarine oil slick, lake ice, ocean ice morphology, and ocean oil slick measurements, and worldwide land masses for snow morphology measurements. Rainfall measurements are required on a global basis.

9.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Rain**

Range:	0-100 mm/hr.
Accuracy:	20%
Sensitivity:	1.0 K
Resolution (Swath):	1 km (limited)
Update Rate:	1 per day
Integration Time:	0.025 seconds
Bandwidth:	920 MHz
Sensor Interference Threshold:	-146 dB(W)
Competing Effects:	Soil moisture (1.4, 2.7 GHz), Snow (1.4, 2.7, 10.7, 19.9, 37 GHz), Lake ice (10.7, 19.9, 37 GHz), Sea state (10.7, 19.9 GHz), Surface temperature (5.0 GHz), and Limited Dynamic Range(1)

- **Lake Ice**

Sensitivity:	1.0 K
Resolution:	2-5 km
Update Rate:	1 per day

(1) Radiometric measurements at a single frequency have a limited dynamic range. To extend the dynamic range simultaneous measurements must be made at a number of frequencies between 6 and 37 GHz. If measurements over land are to be made, observations should be made at even lower frequencies.

- **Lake Ice (cont.)**

Integration Time:	0.2 sec.
Bandwidth:	115 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain, Clouds (19.9, 37.0 GHz), and Snow Cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz).

- **Estuarine Oil Slick**

Sensitivity:	1.0 K
Resolution:	0.2 km
Update Rate:	1 per day
Integration Time:	0.02 sec.
Bandwidth:	1.15 GHz
Sensor Interference Threshold:	-145 dB(W)
Competing Effects:	Sea state (10.7, 19.9 GHz), Rain (19.9, 37.0 GHz), and Water vapor 22.4 GHz).

- **Ocean Ice Morphology**

Range:	Location and type
Sensitivity:	1.0 K
Resolution (Swath):	20 km (800 km)
Update Rate:	1 per day
Integration Time:	0.05 seconds
Bandwidth:	120 MHz

- **Ocean Ice Morphology (cont.)**

Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Rain (19.9, 37.0 GHz), Snow cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz)

- **Ocean Oil Slick**

Sensitivity:	1.0 K
Resolution:	2 km
Update Rate:	1 per day
Integration Time:	0.2 seconds
Bandwidth:	115 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Sea state (10.7, 19.9 GHz), Rain (19.9, 37.0 GHz) and Water vapor 22.4 GHz).

- **Snow Morphology**

Range:	0-20% free water content
Accuracy:	2%
Sensitivity:	1 K
Resolution:	2-5 km
Update Rate:	1 per day
Integration Time:	0.2 seconds

- **Snow Morphology (cont.)**

Bandwidth:	115 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain and Clouds (19.9, 37.0 GHz).

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	4 meters (1 km resolution)

- **Operational Requirements**

All measurements are required once per day. Continuous spacecraft measurements over applicable areas are required to compile this data.

The data acquired in this frequency band must be used in conjunction with radiometric data gathered simultaneously at other frequencies, in order to eliminate competing effects (i.e., rain, clouds, sea state, soil moisture, water vapor, snow, lake ice, surface temperature, etc.).

9.6 STATUS OF TECHNOLOGY AND USE

Development, testing and experimentation is proceeding on the Scanning Multichannel Microwave Radiometer Simulator, Surface Contour Radar, and the Passive Microwave Imaging System. The Electronically Scanning Microwave Radiometer has been flown on Nimbus-5 and -6. The Scanning Multichannel Microwave Radiometer will be flown on Nimbus-G (1978) and Seasat-A (1977), and the Shuttle Imaging Microwave System will be flown on the Shuttle. Operational use is expected in the mid-1980's on the Shuttle, Landsat and Seasat follow-on missions.

9.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is the highest frequency band, below the oxygen rotation lines in the 50-70 GHz region, that is useful for sensing surface phenomena.

The primary applications for this band are measurements of rain, snow and ice morphology and oil slicks, whose maximum sensitivity increases with frequency. The band is also useful for the detection of overcast cloud conditions.

This band covers the lowest rain rates for multi-frequency observations of rainfall.

The required bandwidth (230-1000 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 9.

9.8 SHARING ANALYSIS RESULTS

The 36-37 GHz band is currently allocated to the Fixed and Mobile Service, and is proposed for allocation to the Fixed- and Mobile-Satellite Services. Deletion of the Fixed and Mobile Service has been proposed.

The results presented herein are based on national, as well as international frequency assignment data files and, in some cases, anticipated future use of the band. The assumptions underlying these analyses are that:

- The Fixed and Mobile Service transmitters in this band will be located primarily on land, in highly populated, economically developed areas. Systems will be digitally encoded rather than analog.

- Fixed- and mobile-satellite use in the United States, and elsewhere, will be primarily for government communications on a full-time basis. Operations will be similar to operations of the DSCS.

The results of the sharing analyses are presented below and in Table 9-1. The detailed sharing analyses can be found in bound in Chapter II, Part B, Section 9.

TABLE 9-1

SUMMARY OF SHARING ANALYSES RESULTS

		FIXED AND MOBILE	FIXED AND MOBILE SATELLITE	
			Up-link	Down-link
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-45	+35	-6
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-93	-48	-58
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE	km^2	-	3.6×10^5	-
	%**	-	2%	-
SIMULTANEOUS SHARING FEASIBLE		YES	MARGINAL	YES

* (-) Indicates below interference threshold of -152 dB(W).
** Percentage number is percent of area lost to the radiometer when in view of the interferor.

- **Fixed and Mobile Service**

  - Harmful interference, during simultaneous operations will not be encountered from Fixed and Mobile Service operations due to the low e.i.r.p. envisioned to be used by these systems.

- **Fixed- and Mobile-Satellite Service**

  - Harmful interference from up-link operation on a simultaneous basis will be encountered at isolated areas associated with each earth terminal. It is possible that the spacial density of earth terminals will not be great. However, sharing on a primary co-equal basis is considered marginally feasible.

9.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between space-borne passive microwave sensors and the Fixe` Mobile, Fixed-Satellite and Mobile-Satellite Services in the 36-37 GHz band is considered marginally feasible.

Consequently, the spa⌐ɜ passive services could possibly be allocated on a primary, co-equal basis.

The criteria for the space passive services to share with each active service would be:

- Fixed and Mobile - Emission must conform to the specifications in CCIR Reports 387-2, 609, and 610.

- Fixed and Mobile-Satellite (down-link) - The PFD at the surface of the earth must not exceed -147 dB(W/m^2/4 kHz), or equivalently -21 dB(W/Hz) e.i.r.p.

- Fixed and Mobile-Satellite (up-link) - The earth stations e.i.r.p. must not exceed +86 dBW.

SECTION 10

FREQUENCY BAND 50.2 - 50.4 GHz

ANALYSIS OF PASSIVE REMOTE SENSING
REQUIREMENTS IN THE
50.2-50.4 GHz BAND

10.1 ALLOCATIONS

The existing allocations and proposed changes in the 50.2-50.4 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indic.'e proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
50.0-50.4	~~FIXED-SATELLITE (Earth-to-Space)~~ SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) Sensor	
	NON-GOVERNMENT	
50-51	FIXED FIXED-SATELLITE (Earth-to-Space) MOBILE	

10.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Atmospheric temperature (primary)

10.3 APPLICATION

More effective and efficient management of:

1) Weather forecasting

10.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Surveillance over all areas on a global basis.

10.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- Low Orbiting Nadir Observations

Range:	-70 to +30°C
Accuracy:	1°C
Sensitivity:	0.3 K
Resolution:	10 km
Update Rate:	2 per day
Integration Time:	1.0 seconds
Bandwidth:	235 MHz*
Sensor Interference Threshold:	-157 dB(W)
Competing Effects:	Water vapor (22.4 GHz) Clouds (87.0, 90.0 GHz) Rain (19.9, 37.0 GHz)

*The required bandwidth is wider than the current government allocation proposal.

- **Low Orbiting Limb Observations**

Range:	-70 to +30°C
Accuracy:	1°C
Sensitivity:	0.3 K
Resolution:	2 km (vertical)
Update Rate:	2 per day
Integration Time:	1 second
Bandwidth:	235 MHz
Sensor Interference Threshold:	-157 dB(W)
Competing Effects:	Water vapor (22.4 GHz) Clouds (87.0, 90.0 GHz) Rain (19.9, 37.0 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.2 meters (nadir) 2 x 6 meters (limb)

- **Operational Requirements**

Temperature profile measurements are required twice per day. Continuous spacecraft measurements are required to compile these profiles.

10.6 STATUS OF TECHNOLOGY AND USE

The TIROS Operational Vertical Sounder - Microwave Sounding Unit is planned for launching in 1977 on TIROS-N and subsequently on NOAA's operational TIROS-N series.

Current development and testing are proceeding on the Storm Structure Microwave Spectrometer and the TIROS Operational Vertical Sounder-Microwave Sounder Unit. Operational use will continue in the mid-1980's on meteorological satellites.

10.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for atmospheric temperature measurements in the lowest layer of the atmosphere due to its location near the edge of the 50-70 GHz complex of oxygen rotation lines.

The required bandwidth (235 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 10.

10.8 SHARING ANALYSIS RESULTS

Portions of the 50.2 to 50.4 GHz spectral region are currently allocated to the Fixed Satellite (earth-to-space) service . In the United States, addition of Fixed, Mobile, and Mobile-Satellite (Earth-to-Space) Services is proposed.

The results presented are based on national as well as international frequency assignment data files, and an assessment of anticipated future use of the band.

The assumptions underlying these analyses are that:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Fixed and mobile transmitters will be located in metropolitan areas and would employ 1 km hops.
- Fixed-satellite and mobile-satellite use in the United States, and elsewhere, will be primarily by common carriers or military agencies and would be full time in nature. Systems would use high gain spot beam antennas.

The results of the sharing analyses are presented below and are summarized in Table 10-1. The detailed sharing analyses can be found in Chapter II, Part B, Section 10.

- Fixed and Mobile Service
  - -- No harmful interference to the passive services will result from simultaneous operation of Fixed and Mobile Service transmitters because of small loss of coverage areas.

TABLE 10-1

SUMMARY OF SHARING ANALYSIS RESULTS

		FIXED & MOBILE SERVICES	FIXED & MOBILE SATELLITE SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR		+4.7	+50.
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-143	-120
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	78.5	$4.3x10^4$
	%**	$4.3x10^{-4}$	0.24%
SIMULTANEOUS SHARING FEASIBLE		Yes	Yes***
TIME SHARING FEASIBLE		--	--

*(-) Indicates below interference threshold of -160 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of an interferor.
***Provided that only a small number of Earth Stations are simultaneously in view.

- Fixed-Satellite Service
  - -- Significant harmful interference on a simultaneous operational basis will be encountered only if substantial numbers of earth stations are simultaneously in view of the radiometer.
  - -- Small numbers of earth stations do not cause significant interference because loss of coverage area is small.

10.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne microwave sensors and the Fixed and Mobile Services in the 50.2 to 50.4 GHz band is feasible.

Sharing on a simultaneous operational basis between spaceborne microwave sensors and the Fixed-Satellite Service is feasible if the number of earth stations simultaneously in view is small, that is less than 10.

Consequently, the space passive services could possibly be allocated on a primary, co-equal basis.

SECTION 11

FREQUENCY BAND 51.4 - 59.0 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

51.4-59.0 GHz BAND

11.1 ALLOCATIONS

The existing allocations and proposed changes in the 51.4-59.0 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
51.4-52	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) 412J	
52-54.25	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) 412J	
54.25-58.2	INTER-SATELLITE FIXED MOBILE EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive)	
58.2-59	SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) 412J	

Region 1	Region 2	Region 3
	NON-GOVERNMENT	
NOC 51-52	EARTH EXPLORATION SATELLITE SPACE RESEARCH	
52-54.25	SPACE RESEARCH (Passive) MOD 412J	
54.25-58.2	FIXED MOBILE (except aeronautical mobile) INTER-SATELLITE 410E	
58.2-59	SPACE RESEARCH (Passive) MOD 412J	

ADD 410E The frequency 55 GHz is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 250 MHz of that frequency. Radiocommunication services operating within these limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment.

11.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) ATmospheric temperature (primary)

11.3 APPLICATION

More effective and efficient management of:

1) Weather forecasting

11.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

11.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- **Low Orbiting Nadir Observations**

Range:	-70 to + 30°C
Accuracy:	1°C
Sensitivity:	0.3 K
Resolution:	10 km
Update Rate:	2 per day
Integration Time:	1 sec
Bandwidth:	235 MHz
Sensor Interference Threshold:	-157 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Clouds (87, 90 GHz), Rain(19.9, 37 GHz)

- **Low Orbiting Limb Observations**

Range:	-70 to + 30°C
Accuracy:	1°C
Sensitivity:	0.3 K
Resolution:	2 km (vertical)
Update Rate:	2 per day
Integration Time:	1 sec
Bandwidth:	235 MHz
Sensor Interference Threshold:	-157 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Clouds (87, 90 GHz), Rain (19.9, 37 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	0.2 meters (nadir observations) 2 x 6 meters (limb sounding)

- **Operational Requirements**

Temperature profile measurements are required twice per day. Daily global measurements are required to complie these profiles.

11.6 STATUS OF TECHNOLOGY AND USE

The Scanning Microwave Spectrometer (Nimbus-6) and the Nimbus-5 Microwave Spectrometer have been developed and flown. Current development and testing is proceeding on the Shuttle Imaging Microwave System and Microwave Temperature Sounder. The TIROS Operational Vertical Sounder-Microwave Sounder Unit is planned to be operational on NOAA's TIROS-N series, commencing in 1977.

Current development and testing are proceeding on the Microwave Limb Sounder and Microwave Temperature Sounder. Operational use of the band will continue in the mid-1980's for the Shuttle and meteorological-satellites.

11.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for atmospheric temperature profile measurements due to the oxygen rotation lines that occur within this band.

The required bandwidth (235 MHz per line) is determined by radiometer sensitivity, receiver noise temperature and integration times, all of which are fixed by the application. A derivation of the bandwidth value is presented in Chapter II, Part B, Section 11. The total requested bandwidth of 7.6 GHz is needed to obtain temperature measurements at multiple heights in the atmosphere.

11.8 SHARING ANALYSIS RESULTS

The 51.4-59.0 GHz band is currently or proposed to be allocated to the Inter-Satellite Service, Fixed and Mobile Services, and space passive services. The results presented herein are based on anticipated future use of the band. The assumptions underlying the analyses are that:

- The Fixed and Mobile Service transmitters in this band will be located in highly populated, economically developed areas and will be used for intra-city communications with hop lengths of less than 1 km. Systems will be digital.

- Inter-Satellite Service use of the band will be for geostationary-to-geostationary communications as well as up- and down-links for communications with low orbit spacecraft. Systems are expected to employ spread spectrum techniques. Also, the density of the geostationary utilization is expected to be such that cumulative side-lobe interference will not be an important factor.

The results of the sharing analyses are presented below as well as in Table 11.1. Detailed sharing analyses can be found in Chapter II, Part B, Section 11.

- <u>Fixed and Mobile Service</u>
  Harmful interference will not be encountered from Fixed and Mobile Service operations due to high atmospheric absorption in this band and the low e.i.r.p.'s envisioned to be employed by these systems.

- <u>Inter-Satellite Service</u>
  Localized area of interference could be encountered by a spaceborne sensor when: 1) passing through the down-link tracking beam of the geostationary satellite, 2) in close proximity (150 km) to an up-link transmitting low-orbiting satellite, and 3) pointing (for a limb sounder) directly at the geostationary satellite.

TABLE 11-1

SUMMARY OF SHARING ANALYSES RESULTS

		FIXED AND MOBILE	INTER-SATELLITE SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-98	68
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-155	-75
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	-	$\sim 6.5 \times 10^6$
	%**	-	~ 3
SIMULTANEOUS SHARING FEASIBLE		YES	YES
TIME SHARING FEASIBLE			

*(-) Indicates below interference threshold of -157 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of the interferor.
***Worst case upperbound for main-to-main beam coupling, which for forseeable EES orbits and intersatellite separation will not occur.

ORIGINAL PA...
OF POOR QUALITY

The first mode produces marginal interference, yet even if higher levels were encountered, the probability of being within the tracking beam is negligible. Likewise, the second mode occurs so infrequently as to be negligible. The third mode provides a fixed interference area through the sensor main beam coupling with the geosatellite side-lobe or main beam. The former produces interference; however, the area of interference is of negligible impact to data measurements. The latter coupling, which produces interference, can only occur for geosatellite separations on the order of 160° and only for two particular EES orbit configurations - such a condition will never occur in practice.

11.9 CONCLUSIONS

Sharing on a simultaneous operational basis between passive microwave sensors and the Fixed, Mobile and Inter-Satellite Services in the 51.4-59.0 GHz band is feasible.

Consequently, a primary, co-equal allocation is feasible.

SECTION 12

FREQUENCY BAND 64.0 - 65.0 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

64.0-65.0 GHz BAND

12.1 ALLOCATIONS

The existing allocations and proposed changes in the 62.4-65.0 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
64-65	<u>EARTH EXPLORATION SATELLITE (Passive)</u> SPACE RESEARCH (Passive) MOD 412J	
	NON-GOVERNMENT	
64-65	SPACE RESEARCH (Passive) 412J	

12.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Atmospheric temperature (primary)

12.3 APPLICATION

More effective and efficient management of:

1) Weather forecasting

12.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

12.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- Low Orbiting Nadir Observations

Range:	-70 to + 30°C
Accuracy:	3°C
Sensitivity:	1 K
Resolution:	10 km
Update Rate:	2 per day
Integration Time:	1 sec
Bandwidth:	235 MHz
Sensor Interference Threshold:	-157 dB(W)
Competing Effects:	Water Vapor (22.4 GHz) Clouds (87,906 GHz) Rain (19.9, 37 GHz)

- <u>Low Orbiting Limb Observations</u>

Range:	-70 to + 30°C
Accuracy:	3°C
Sensitivity:	0.3 K
Resolution:	2 km (vertical)
Update Rate:	2 per day
Integration Time:	1 sec.
Bandwidth:	235 MHz
Sensor Interference Threshold:	-157 dB(W)
Competing Effects:	Water vapor (22.4 GHz) Clouds (87,906 GHz) Rain (19.9, 37 GHz)

- <u>Spacecraft Parameters</u>

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	0.2 meters (nadir observations) 2x6 meters (limb sounding)

- <u>Operational Requirements</u>

Temperature profile measurements are required twice per day. Continuous satellite measurements are required to compile these profiles.

12.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on the Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use of this band is expected in the mid-1980's on the Shuttle and meteorological-satellites.

12.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for atmospheric temperature profile measurements due to the oxygen rotation lines that occur within this band.

This required bandwidth (235 MHz per line) is determined by radiometer sensitivity, receiver noise temperature and integration times, all of which are fixed by the application. A derivation of the bandwidth value is presented in Chapter II, Part B, Section 12. The total requested bandwidth of 1000 MHz is needed to obtain temperature measurements at multiple heights in the atmosphere.

12.8 SHARING ANALYSIS RESULTS

The 64.0-65.0 GHz frequency band is currently allocated to the Space Research (passive). It is proposed that this band be shared with the Earth Exploration Satellite (passive) Service. Since the above passive services can inherently share with another passive service, frequency sharing in the 64.0-65.0 GHz band is feasible.

12.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Space Research (passive) service is feasible consequently, a primary, co-equal allocation is feasible.

SECTION 13

FREQUENCY BAND 86 - 92 GHz

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 86-92 GHz Band

13.1 ALLOCATIONS

The existing allocations and proposed changes in the 86-92 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

REGION 1	REGION 2	REGION 3
	NON-GOVERNMENT	
86-92	RADIO ASTRONOMY SPACE RESEARCH (Passive) MOD 412J	
	GOVERNMENT	
86-92	RADIO ASTRONOMY SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive)	

13.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Clouds (primary)
2) Snow morphology (primary)
3) Ice morphology (primary)
4) Oil slicks (primary)

13.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Water resources

13.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Geographical coverage requirements include worldwide estuarine, lake, costal and open ocean areas for estuarine oil slick, lake ice, ocean ice morphology, and ocean oil slick measurements, and worldwide land masses for snow morphology measurement. Cloud measurement are required on a global basis.

13.5 SENSOR PERFORMANCE AND OPERATIONAL REQUIREMENTS

- Clouds

Range:	0-3 gm/m^3
Accuracy:	0.1 gm/m^3

Sensitivity:	1.0 K
Resolution (Swath):	1 km (limited)
Update Rate:	2 per day
Integration Time:	0.003 seconds
Bandwidth:	6000 MHz
Competing Effects:	Soil moisture (1.4,2.6 GHz) Snow (1.4,2.7.10.7,19.9,37 GHz) Lake ice (10.7,19.9,37 GHz) Sea State (10.7,19.9 GHz) Surface temp. (5 GHz) Rain (19.9, 37 GHz) Water vapor (22.4 GHz) Atmosphere temp. (52 GHz)

- Lake Ice

Sensitivity:	1.0 K
Resolution (Swath):	2-5 km (100 Km)
Update Rate:	1 per day
Integration Time:	0.004 seconds
Bandwidth:	5.75 GHz
Sensor Interference Threshold:	-138 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain, Clouds (19.9, 37.0 GHz), and Snow Cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz).

- Estuarine Oil Slick

Sensitivity:	1.0 K
Resolution:	0.2 km

Update Rate:	1 per day
Integration Time:	0.02 seconds
Bandwidth:	1.15 GHz
Sensor Interference Threshold:	-145 dB(W)
Competing Effects:	Sea state (10.7, 19.9 GHz), Rain (19.9, 37.0 GHz), and Water vapor 22.4 GHz).

- <u>Ocean Ice Morphology</u>

Range:	Location and type
Sensitivity:	1.0 K
Resolution (Swath):	20 Km (800 Km)
Update Rate:	1 per day
Integration Time:	0.2 seconds
Bandwidth:	120 MHz
Sensor Interference Threshold:	-155 dB(W)
Competing Effects:	Rain (19.9, 37.0 GHz), Snow cover (1.4, 2.7, 10.7, 19.9, 37.0 GHz)

- <u>Ocean Oil Slick</u>

Sensitivity:	1.0 K
Resolution (Swath):	2 Km (100 Km)
Update Rate:	1 per day
Integration Time:	0.004 seconds

Bandwidth:	5.75 GHz
Sensor Interference Threshold:	-138 dB(W)
Competing Effects:	Sea state (10.7, 19.9 GHz), Rain (19.9, 37.0 GHz) and Water vapor 22.4 GHz).

- Snow Morphology

Range:	0-20% free water content
Accuracy:	2%
Sensitivity:	1.0 K
Resolution (Swath):	2-5 km (100 Km)
Update Rate:	1 per day
Integration Time:	0.004 seconds
Bandwidth:	5.75 GHz
Sensor Interference Threshold:	-138 dB(W)
Competing Effects:	Water vapor (22.4 GHz), Rain and Clouds (19.9, 37.0 GHz).

- Spacecraft Parameters

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	1.6 meters (1 Km resolution)

- <u>Operational Requirements</u>

All other measurements are required once per day. Continuous spacecraft measurements are required to compile this data.

Data acquired in this frequency band must be used in conjunction with measurements in other bands to eliminate competing effects.

13.6 STATUS OF TECHNOLOGY AND USE

The Shuttle Imaging Microwave System is being developed for Shuttle missions. Studies are proceeding on the development of future instruments to be used in this band for high resolution low-earth orbit, and for syncronous orbit, imaging. Operational use of this band is expected in the mid-80's on the Space Shuttle, Meteorological, Landsat and Seasat follow-on missions.

13.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required to obtain surface information about oil slicks, snow, and ice in the atmospheric window between the 50-70 GHz oxygen rotational line complex and the 118.75 GHz isolated oxygen line. This band is also important for high resolution rain and cloud measurements.

The required bandwidth (6000 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration times, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 13.

13.8 SHARING ANALYSIS RESULTS

The 86-92 GHz frequency band is currently allocated to Radio Astronomy and Space Research (passive). It is proposed that this band be shared with the Earth Exploration Satellite (passive) Service. Since the above passive services can inherently share the band, frequency sharing in the 86-92 GHz band is feasible.

13.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Radio Astronomy, Space Research (passive), and Earth Exploration Satellite (passive) Services is feasible.

Consequently, a primary, co-equal allocation is feasible.

SECTION 14

FREQUENCY BAND 100 - 102 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

100-102 GHz BAND

14.1 ALLOCATIONS

The existing allocations and proposed changes in the 100-102 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
100-101	~~AERONAUTICAL-MOBILE-SATELLITE~~ ~~MARITIME-MOBILE-SATELLITE~~ ~~AERONAUTICAL-RADIONAVIGATION-SATELLITE~~ ~~MARITIME-RADIONAVIGATION-SATELLITE~~ SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) 412J	
ADD 412J		
101-102	SPACE RESEARCH (Passive) MOD 412J	

Region 1	Region 2	Region 3
	NON-GOVERNMENT	
95-101	AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE-SATELLITE MARITIME MOBILE MARITIME MOBILE-SATELLITE AERONAUTICAL RADIONAVIGATION (R) AERONAUTICAL RADIONAVIGATION-SATELLITE MARITIME RADIONAVIGATION MARITIME RADIONAVIGATION-SATELLITE	
101-102	SPACE RESEARCH (Passive) MOD 412J	

14.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric nitrous oxide (primary)
2) Stratospheric ozone (primary)

14.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

14.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

14.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- **Limb Scanning Nitrous Oxide**

Range:	–
Accuracy:	–
Sensitivity:	0.2 K
Resolution:	2 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Limb Scanning Ozone**

Range:	–
Accuracy:	–
Sensitivity:	0.2 K
Resolution:	2 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	1 x 4 meter (limb scanning)

- <u>Operational Requirements</u>

  Limb stratospheric trace constituent measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

14.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on the Microwave Limb Sounder for the Shuttle and meteorological satellites. Operational use of this band is expected in the mid-1980's on the Shuttle and Meteorological satellites.

14.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide and ozone profile measurements. This band was selected because it contains ozone (101.7 GHz) and nitrous oxide (100.5 GHz) rotation lines.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature, and integration times, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 14.

14.8 SHARING ANALYSIS RESULTS

There are no meaningful system technical characteristics available upon which to base a sharing analysis. Since there are other frequencies below 100 GHz (e.g., 45-50 GHz and 66-71 GHz) which are proposed for allocation to the same services as described in Section 14.1, and since planning for equipment has not progressed beyond 5250 MHz, it is not reasonable to expect use of the 100 GHz band by services other than the passive services before the year 2000.

14.9 CONCLUSIONS ON SHARING

The probability appears very low, that there will be occupancy of this band by the designated services by the year 2000. It is proposed that all services presently allocated and proposed for use in the band 100-102 GHz be deleted with the exception of Space Research (passive) and Earth Exploration Satellite (passive) Services.

SECTION 15

FREQUENCY BAND 105.0 - 126.0 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

106-126 GHz BAND

15.1 ALLOCATIONS

The existing allocations and proposed changes in the 105-126 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
105-<u>116</u>	~~INTER-SATELLITE~~ <u>RADIO ASTRONOMY</u> <u>SPACE RESEARCH (Passive)</u> <u>EARTH EXPLORATION SATELLITE (Passive)</u> ~~412K~~	
<u>116</u>-<u>126</u>	INTER-SATELLITE <u>SPACE RESEARCH (Passive)</u> <u>EARTH EXPLORATION SATELLITE (Passive)</u>	

Region 1	Region 2	Region 3
	NON-GOVERNMENT	
106-~~130~~ 116	~~INTER-SATELLITE~~ RADIO ASTRONOMY SPACE RESEARCH (Passive) MOD 412J ~~412K~~	
116-130	INTER-SATELLITE FIXED MOBILE ~~412K~~ 410F	

ADD 410F The frequency 120 GHz is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 500 MHz of that frequency. Radiocommunication services operating within these limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment.

15.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Atmospheric temperature (primary)

2) Stratospheric ozone (primary)

3) Stratospheric carbon monoxide (primary)

4) Stratospheric nitrous oxide (primary)

15.3 APPLICATION

More effective and efficient management of:

1) Weather forecasting
2) Environmental regulations
3) Air pollution (stratospheric)

15.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

15.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Geostationary Nadir Temperature Profile Observation Requirements

Range:	-70 to + 30°C
Accuracy:	1°C
Sensitivity:	0.2 K
Resolution:	100 km
Update Rate:	4 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Rain (150 GHz) Water vapor (183 GHz)

- **Limb Sounder Observations - All Measurements**

Range:	----
Accuracy:	----
Sensitivity:	0.2 K
Resolution:	2 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

1) Geostationary Satellite Observations

Orbital Altitude:	35,780 km
Antenna:	1 meter

2) Limb Sounder Observations

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	0.75 x 3

- Operational Requirements

  Geostationary satellite observations are required once every 6 hours. Limb sounder observations are required from once per day to once per week. Continuous satellite measurements are required to compile phenomena profiles.

15.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on the Shuttle Imaging Microwave System, the Storm Structure Microwave Spectrometer and the Microwave Limb Sounder. Operational use is expected in the mid-1980's for the Shuttle and meteorological-satellites.

15.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for temperature profiling and stratospheric ozone, carbon monoxide, and nitrous oxide measurements. This band was selected because it contains oxygen, ozone, carbon monoxide and nitrous oxide rotation lines.

The required bandwidth (1850 MHz per line) is determined by radiometer sensitivity, receiver noise temperature and integration times, all of which are fixed by the application. Lines occur at 110.8 (O_3), 115.27 (CO), 118.7 (O_2), and 125.6 (N_2O) GHz. Also, in order for geostationary temperature profiles to be measured, multiple measurements about the 118.7 GHz oxygen line are required. Consequently, a minimum overall bandwidth from 105-126 GHz is required. A derivation of the required bandwidth per line is contained in Chapter II, Part B, Section 15.

15.8 SHARING ANALYSIS RESULTS

Portions of the 106-126 GHz band are currently allocated to the Inter-Satellite Service in Regions 1, 2 and 3 and is proposed for allocation to the Fixed and Mobile Services.

The results presented herein are based on anticipated future use of the band. The assumptions underlying the analyses are that:

- The Fixed and Mobile Service transmitters in this band will be located in highly populated, economically developed areas and will be used for intra-city communications with hop lengths of less than 1 km. Systems will be digital.

- Inter-Satellite Service use of the band will be for geostationary-to-geostationary communications as well as up- and down-links for communications with low orbit spacecraft. Systems are expected to employ spread spectrum techniques. Also, the density of the geostationary utilization is expected to be such that cumulative side-lobe interference will not be an important factor.

The results of the sharing analyses are presented below as well as in Table 15-1. Detailed sharing analyses can be found in Chapter II, Part B, Section 15.

- Fixed and Mobile Service

  Harmful interference will not be encountered from Fixed and Mobile Service operations due to high atmospheric absorption in the band and the low e.i.r.p.'s envisioned to be employed by these systems.

TABLE 15-1

SUMMARY OF SHARING ANALYSES RESULTS

		FIXED AND MOBILE	INTER-SATELLITE SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-14.7	79
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-149	-64
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	-	$\sim 6.5 \times 10^6$
	%**	-	~ 3
SIMULTANEOUS SHARING FEASIBLE			
TIME SHARING FEASIBLE		YES	YES

*(-) Indicates below interference threshold of -150 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of the interferor.
***Worst case upperbound for main-to-main beam coupling, which for forseeable EES orbits and intersatellite separation will not occur.

- **Inter-Satellite Service**

  Localized area of interference could be encountered by a spaceborne sensor when: 1) passing through the down-link tracking beam of the geostationary satellite, 2) in close proximity (150 km) to an up-link transmitting low-orbiting satellite, and 3) pointing (for a limb sounder) directly at the geostationary satellite.

  The first mode produces marginal interference, yet even if higher levels were encountered, the probability of being within the tracking beam is negligible. Likewise, the second mode occurs so infrequently as to be negligible. The third mode provides a fixed interference area through the sensor main beam coupling with the geosatellite side-lobe or main beam. The former produces interference; however, the area of interference is of negligible impact to data measurements. The latter coupling, which produces interference, can only occur for geosatellite separations on the order of 160° and only for two particular EES orbit configurations - such a condition will never occur in practice.

15.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between passive microwave sensors and the Fixed, Mobile and Inter-Satellite Services in the 105-126 GHz band is feasible.

Consequently, a primary, co-equal allocation is also feasible.

SECTION 16

FREQUENCY BAND 150-151 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

150-151 GHz BAND

16.1 ALLOCATIONS

The existing allocations and proposed changes in the 150-151 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
150-151	~~FIXED-SATELLITE (Space-to-Earth)~~ EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) 412J	
Add 412L		
	NON-GOVERNMENT	
150-152	FIXED-SATELLITE (Space-to-Earth) FIXED MOBILE 412M	
Add 412M		

16.2 MEASUREMENT

Thermal microwave earth emission to determine:

1) Stratospheric nitrous oxide (primary)

16.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

16.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

16.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Scanning Nitrous Oxide

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	2 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz*
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water vapor (183 GHz)

*The required bandwidth is wider than the current government allocation proposal.

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.5 x 2.5 meter (limb scanning)

- **Operational Requirements**

Limb nitrous oxide measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

16.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on Microwave Limb Sounder for the shuttle and meteorological-satellites. Operational use is expected in the mid-1980's on the shuttle and meteorological-satellites.

16.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide measurements. This band was selected because it contains a nitrous oxide rotation line at 150.7 GHz.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 16.

16.8 SHARING ANALYSIS RESULTS

Portions of the 150 to 151 GHz spectral/region are currently allocated to the Fixed-Satellite space-to-Earth Service. In the United States, deletion of the Government sector Fixed-Satellite (space-to-Earth) Service is proposed. In the private sector this service would remain and the Fixed and Mobile Services would be added.

The results presented are based on national as well as international frequency assignment data files, and an assessment of anticipated future use of the band.

The assumptions underlying these analyses are that:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Fixed and mobile transmitters will employ 1 km hops.
- Fixed-satellite use in the United States, and elsewhere, will be primarily by common carriers or military agencies and would be full time in nature. Systems would use high gain spot beam antennas.

The results of the sharing analyses are presented below and are summarized in Table 16-1. The detailed sharing analyses can be found in Chapter 2, Part B, Section 16.

- Fixed and Mobile Service

  - No harmful interference to the passive services will result from simultaneous operation of Fixed and Mobile Service transmitters, because of low power transmission employed.

- Fixed-Satellite Service

  - Harmful interference on a simultaneous operational basis will be encountered only if the radiometer is in the main beam of the geostationary satellite and receives a signal by backscatter from the Earth's atmosphere. This interference is not regarded as being significant since the loss of coverage is small.

16.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne microwave sensors and the Fixed and Mobile Services in the 150 to 151 GHz band is feasible.

Consequently, a primary co-equal allocation is feasible.

TABLE 16-1

SUMMARY OF SHARING ANALYSIS RESULTS

	FIXED & MOBILE SERVICES	FIXED & MOBILE SATELLITE SERVICE
MAZIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR	-60	+4
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR	-175	-572
LOSS OF COVERAGE AREA FOR A SINGLE INTERFERENCE SOURCE (km^2)	--	$4x10^3$
%**	--	$2x10^{-3}$
SIMULTANEOUS SHARING FEASIBLE	Yes	Yes
TIME SHARING	--	--

*(-) Indicates below interference threshold of -153 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of the interferor.

SECTION 17

FREQUENCY BAND 174.5-176.5

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 174.5-176.5 GHz BAND

17.1 ALLOCATIONS

The existing allocations and proposed changes in the 174.5-176.5 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
174.5-176.5	~~INTER-SATELLITE~~ EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) 412L	
Add 412L		
	NON-GOVERNMENT	
170-~~182~~ 175	FIXED MOBILE (except Aeronautical Mobile ~~INTER-SATELLITE~~ 412P	
Add 412P		

17.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric nitrous oxide (primary)

17.3 APPLICATION

More effective and efficient management of:

1) Environmental Regulations
2) Air pollution (stratospheric)

17.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

17.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- **Limb Scanning Nitrous Oxide**

Range:	----
Accuracy:	----
Sensitivity:	0.[illegible] K
Resolution:	2 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	0.5 x 2 meter (limb scanning)

- **Operational Requirements**

  Limb nitrous oxide measurements are required once per week. Continuous satellite measurements are required to compile phenomena profiles.

17.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use is expected in the mid-1980's on the Shuttle and meteorological-satellites.

17.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide profile measurements. This band was selected because it contains a nitrous oxide rotation line at 175.8 GHz.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature and integra-time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 17.

17.8 SHARING ANALYSIS RESULTS

The 174.5-176.5 GHz band is currently allocated to the Inter-Satellite Service in Regions 1, 2 and 3 and is proposed for allocation to the Fixed and Mobile Services.

The results presented herein are based on anticipated future use of the band. The assumptions underlying the analyses are that:

- The Fixed and Mobile Service transmitters in this band will be located in highly populated, economically developed areas and will be used for intra-city communications with hop lengths of less than 1 km. Systems will be digital.

- Inter-Satellite Service use of the band will be for geostationary-to-geostationary communications as well as up- and down-links for communications with low orbit spacecraft. Systems are expected to employ spread spectrum techniques. Also, the density of the geostationary utilization is expected to be such that cumulative side-lobe interference will not be an important factor.

The results of the sharing analyses are presented below as well as in Table 24-1. Detailed sharing analyses can be found in Chapter II, Part B, Section 24.

- <u>Fixed and Mobile Service</u>
  Harmful interference will not be encountered from Fixed and Mobile Service operations due to high atmospheric absorption in the band and the low e.i.r.p.'s envisioned to be employed by these systems.

TABLE 17-1

SUMMARY OF SHARING ANALYSES RESULTS

		FIXED AND MOBILE	INTER-SATELLITE SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		-44	80
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-178	-63
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	-	$\sim 6.5 \times 10^6$
	%**	-	~ 3
SIMULTANEOUS SHARING FEASIBLE		YES	YES
TIME SHARING FEASIBLE			

*(-) Indicates below interference threshold of -150 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of the interferor.
***Worst case upperbound for main-to-main beam coupling, which for forseeable EES orbits and intersatellite separation will not occur.

- **Inter-Satellite Service**

  Localized area of interference could be encountered by a spaceborne sensor when: 1) passing through the down-link tracking beam of the geostationary satellite, 2) in close proximity (150 km) to an up-link transmitting low-orbiting satellite, and 3) pointing (for a limb sounder) directly at the geostationary satellite.

  The first mode produces marginal interference, yet even if higher levels were encountered, the probability of being within the tracking beam is negligible. Likewise, the second mode occurs so infrequently as to be negligible. The third mode provides a fixed interference area through the sensor main beam coupling with the geosatellite side-lobe or main beam. The former produces interference; however, the area of interference is of negligible impact to data measurements. The latter coupling, which produces interference, can only occur for geosatellite separations on the order of 160° and only for two particular EES orbit configurations - such a condition will never occur in practice.

17.9 CONCLUSIONS

Sharing on a simultaneous operational basis between passive microwave sensors and the Fixed, Mobile and Inter-Satellite Services in the 174.5-176.5 GHz band is feasible.

Consequently, a primary, co-equal allocation is feasible.

SECTION 18

FREQUENCY BAND 182-185 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

182-185 GHz BAND

18.1 ALLOCATIONS

The existing allocations and proposed changes in the 182-185 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

REGION 1	REGION 2	REGION 3
	NON-GOVERNMENT	
182-185 GHz	Space Research (passive) <u>Radio Astronomy</u>	
	GOVERNMENT	
182-185 GHz	Space Research (passive) <u>Earth Exploration Satellite (passive)</u> <u>Radio Astronomy</u>	

18.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric water vapor (primary)

2) Stratospheric ozone (primary)

18.3 APPLICATION

More effective and efficient management of:

1) Weather forecasting

2) Environmental regulations

3) Air pollution (stratospheric)

18.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

18.5 SENSOR PERFORMANCE AND ORBITAL PARAMETERS

- Geostationary Nadir Water Vapor and Ozone Observation Requirements

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	100 km
Update Rate:	4 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Sea Ice (1.4, 10.7, 19.9 GHz), Clouds (37, 90 GHz), Rain (19.9, 37 GHz), Atmospheric Temperature (52 GHz)

- **Limb Sounder Water Vapor and Ozone Observations**

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	2 km (vertical)
Update Rate:	4 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Sea Ice (1.4, 10.7, 19.9 GHz), Clouds (37, 90 GHz) Rain (19.9, 37 GHz) Atmospheric Temperature (52 GHz)

- **Spacecraft Parameters**

1) **Geostationary Satellite Observations**

Orbital Altitude:	35,780 km
Antenna:	0.6 meter

2) **Limb Sounder Observations**

Orbital Altitude:	500 km, circular
Inclination:	70-100° (for world-wide coverage)
Antenna:	0.5 x 2 meter

- Operational Requirements

Geostationary and limb sounder satellite observations are required once every 6 hours. Continuous spacecraft measurements are required to compile this data.

18.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on the 94/183 GHz radiometer for high resolution low earth orbit, applications and for synchronous orbiting imaging. The Microwave Limb Sounder is being developed for the Shuttle and meteorological-satellites. Operational use of this band is expected in the mid-1980's on the Shuttle, Met-Sat, Landsat and Seasat follow-on missions.

18.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for atmospheric water vapor and ozone profile measurements due to the rotation lines that occurs within this band.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. The lines occur at 184.7 GHz for ozone and 183.3 GHz for water vapor. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 18.

18.8 SHARING ANALYSIS RESULTS

The 182-185 GHz frequency band is currently allocated to Space Research (passive). It is proposed that this band be shared with the Earth Exploration Satellite (passive) and the Radio Astronomy Services. Since the above passive services can inherently share the band, frequency sharing in the 182-185 GHz band is feasible.

18.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between space-borne passive microwave sensors and the Space Research (passive), Radio Astronomy, and Earth Exploration Satellite (passive) Services is feasible.

Consequently, a primary, co-equal allocation is feasible.

SECTION 19

FREQUENCY BAND 200-201.5 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

200-201.5 GHz BAND

19.1 ALLOCATIONS

There are no existing allocations in the 200-201.5 GHz frequency band. Proposed allocations are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions.

Region 1	Region 2	Region 3
	GOVERNMENT	
200-201.5	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive)	

	NON-GOVERNMENT	
200-217	FIXED MOBILE	

19.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric nitrous oxide (primary)

19.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

19.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

19.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Scanning Nitrous Oxide

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	2 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

*The required bandwidth is wider than the current government allocation proposal.

- <u>Spacecraft Parameters</u>

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	0.5 x 2 meter (limb scanning)

- <u>Operational Requirements</u>

  Limb nitrous oxide measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

19.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are continuing on M rowave Limb Sounder for use on meteorological-satellites. Operational use is expected in the mid-1980's.

19.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide profile measurements. This band was selected because it contains a nitrous oxide rotation line at 200.9 GHz.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 19.

19.8 SHARING ANALYSIS RESULTS

The 200-201.5 GHz band is not currently allocated to any services. Proposed allocations include the Fixed and Mobile Services.

The following assumptions underline the sharing analysis:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Fixed and Mobile transmitters will employ hop lengths of less than 1 km.

The results are summarized below as well as in Table 19-1.

- Harmful interference on a simultaneous operational basis will not occur to passive remote sensors. The number of systems required to cause interference is very much greater than any projected use of the band.

TABLE 19-1

SUMMARY OF SHARING ANALYSIS RESULTS

		FIXED AND MOBILE
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) IN MAIN BEAM OF ONE INTERFEROR		- 42
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-176
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	----
	%	----
SIMULTANEOUS SHARING FEASIBLE		YES

* (-) Indicates below interference threshold of -150 dB(W).

19.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between the Fixed and Mobile Services and the Earth Exploration Satellite Service (passive) is feasible due to the low required e.i.r.p. of digitally encoded fixed and mobile systems, and high atmospheric losses, in the 200-201.5 GHz band.

Consequently, a primary, co-equal allocation between the space passive services and the Fixed and Mobile Services is feasible. The criteria for sharing with digital fixed and mobile systems is that these systems conform to the specifications of CCIR Reports 387-2, 609, and 610.

SECTION 20

FREQUENCY BAND 225-240 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

225-240 GHz BAND

20.1 ALLOCATIONS

The existing allocations and proposed changes in the 225-240 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
225-230	~~FIXED-SATELLITE~~ RADIO ASTRONOMY SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) 412J	
Add 412J		
230-240	RADIO ASTRONOMY SPACE RESEARCH (Passive) EARTH EXPLORATION SATELLITE (Passive) 412J	

Region 1	Region 2	Region 3
	NON-GOVERNMENT	
221-229	FIXED-SATELLITE FIXED MOBILE	
229-230	FIXED-SATELLITE FIXED MOBILE RADIO ASTRONOMY MOD 412J	
230-240	EARTH EXPLORATION SATELLITE (Passive) RADIO ASTRONOMY SPACE RESEARCH (Passive) MOD 412J	

20.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric nitrous oxide (primary)
2) Stratospheric carbon monoxide (primary)
3) Stratospheric ozone (primary)

20.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

20.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

20.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Sounder Nitrous Oxide, Carbon Monoxide, and Ozone Observations

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for worldwide coverage)
Antenna:	0.4 x 1.5 meter (limb scanning)

- **Operational Requirements**

Limb stratospheric trace constituent measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

20.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use is expected in the mid-1980's.

20.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is desired for stratospheric ozone, carbon monoxide and nitrous oxide profile measurements due to the rotation lines that occur within the band.

The required bandwidth (1850 MHz per line) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. The lines occur at 226.1(N_2O), 230.5(CO), 235.7(O_3), 237.1(O_3) and 239.1(O_3). Consequently, a total bandwidth of from 225-240 GHz is required. A derivation of the required bandwidth per line is contained in Volume II, Part B, Section 20.

20.8 SHARING ANALYSIS RESULTS

Portions of the 225-240 GHz spectral region are currently allocated to the Fixed Satellite and Radio Astronomy Services. In the United States, deletion of Fixed Satellite Services and addition of Fixed and Mobile Services are proposed.

The results are based on national as well as international frequency assignment data files, and an assessment of anticipated future use of the band.

The assumptions underlying these analyses are that:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Fixed and mobile transmitters will employ 1 km hops.
- Fixed-Satellite use in the United States, and elsewhere, is not anticipated in the foreseeable future because development of earth station and satellite equipment would be excessively costly. Sufficient spectrum space is available at more readily attainable frequencies.

The results of the sharing analyses for the Fixed and Mobile Services are presented below and are summarized in Table 20-1. The detailed sharing analyses can be found in Chapter II, Part B, Section 20.

TABLE 20-1

SUMMARY OF SHARING ANALYSIS RESULTS

		FIXED & MOBILE SERVICES
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR		- 41.5
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-325
LOSS OF COVERAGE AREA	(km^2)	--
	%**	--
SIMULTANEOUS SHARING FEASIBLE		YES
TIME SHARING		--

* (-) Indicates below interference threshold of -150 dB(W).
**Percentage number is percent of area lost to the radiometer when in view of the interferor.

- Fixed and Mobile Service

  -- No harmful interference to the passive services will result from simultaneous operation of Fixed and Mobile Service transmitters, because of low powers utilized.

20.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne microwave sensors and the Fixed and Mobile Services in the 225-240 GHz band is feasible.

The allocation for the Fixed-Satellite Service should be deleted, since it will be impractical to use the band in the foreseeable future for this application.

Consequently, a primary, co-equal allocation is feasible.

SECTION 21

FREQUENCY BAND 250-252 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

250-252 GHz BAND

21.1 ALLOCATIONS

The existing allocations and proposed changes in the 250-252 GHz frequency band are given below for Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
250-252	~~AERONAUTICAL-MOBILE-SATELLITE~~ ~~MARITIME-MOBILE-SATELLITE~~ ~~AERONAUTICAL-RADIONAVIGATION-SATELLITE~~ ~~MARITIME-RADIONAVIGATION-SATELLITE~~ EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive)	
	NON-GOVERNMENT	
250-265	AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE-SATELLITE MARITIME MOBILE MARITIME MOBILE-SATELLITE AERONAUTICAL RADIONAVIGATION (R) AERONAUTICAL RADIONAVIGATION-SATELLITE MARITIME RADIONAVIGATION MARITIME RADIONAVIGATION-SATELLITE	

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-100° (for world-wide coverage)
Antenna:	0.4 x 1.5 meter (limb scanning)

- **Operational Requirements**

Limb nitrous oxide constituent measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

21.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on the Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use of this band is expected in the mid-1980's.

21.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide profile measurements. This band was selected because it contains a nitrous oxide rotation line at 251.26 Hz.

The required bandiwdth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration times, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 21.

21.8 SHARING ANALYSIS RESULTS

There are no meaningful system technical characteristics available upon which to base a sharing analysis. Since there are other frequencies below 250 GHz (e.g., 45-50 GHz and 66-71 GHz) which are proposed for allocation to the same services as described in Section 21.1, and since planning for equipment has not progressed beyond 5250 MHz, it is not reasonable to expect use of the 250 GHz band before the year 2000.

21.9 CONCLUSIONS ON SHARING

The probability appears very low that there will be occupancy of this band by the designated Services by the year 2000. It is therefore proposed that all services presently allocated and proposed for use in the band 250-252 GHz be deleted with the exception of Space Research (passive) and Earth Exploration Satellite (passive) Services.

SECTION 22

FREQUENCY BAND 275-277 GHz

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 275-277 GHz BAND

22.1 ALLOCATIONS

There are no existing international allocations above 275 GHz. The proposed allocations in the 275-277 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions, and dashed items indicate proposed deletions.

Region 1	Region 2	Region 3
	GOVERNMENT	
275-277	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive)	

Region 1	Region 2	Region 3
	NON-GOVERNMENT	
275-300	FIXED MOBILE ADD 412Q	

ADD 412Q Radio astronomy observations on the N_2H^+, CH and CH^+ lines are being carried out in a number of countries under national arrangements. In making assignments to stations in the fixed and mobile services, administrations are urged to take all practicable steps to protect radio astronomy observations from harmful interference, particularly from airborne or spaceborne transmitters, in the frequencies 279.5 GHz, 453 GHz, 535 GHz & 1000 GHz.

22.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric nitrous oxide (primary)

22.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

22.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

22.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Scanning Nitrous Oxide

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.4 x 1.5 meter (limb scanning)

- **Operational Requirements**

Limb nitrous oxide measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

22.6 STATUS OF TECHNOLOGY AND USE

Studies are proceeding on the development of future instruments to be used in this band. Operational use of this band is expected in the mid-1980's on the space Shuttle and on meteorological-satellites.

22.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide profile measurements. This band was selected because it contains a nitrous oxide rotation line at 276.3 GHz.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 22.

22.8 SHARING ANALYSIS RESULTS

The 275-277 GHz band is not currently allocated. Proposed additions include the Fixed and Mobile Services.

The following assumptions underline the sharing analysis:

- The Fixed and Mobile Service operation in this band will employ high speed broadband digital transmissions.
- Fixed and Mobile transmitters will employ hop lengths of less than 1 km.

The results are summarized below as well as in Table 22-1.

- Harmful interference on a simultaneous operational basis will not occur to passive remote sensors. The number of systems required to cause interference is very much greater than any projected use of the band.

TABLE 22-1

SUMMARY OF SHARING ANALYSIS RESULTS

		FIXED AND MOBILE
MAXIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD) IN MAIN BEAM OF ONE INTERFEROR		- 39
MINIMUM RECEIVED POWER (dB RELATIVE TO INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		- 173
LOSS OF COVERAGE AREA FROM SINGLE INTERFERENCE SOURCE	km^2	----
	%	----
SIMULTANEOUS SHARING FEASIBLE		YES

* (-) Indicates below interference threshold of -150 dB(W).

22.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between the Fixed and Mobile Services and the Earth Exploration Satellite Service (passive) is feasible due to the low required e.i.r.p. of digitally encoded fixed and mobile systems in the 275-277 GHz band.

Consequently, a primary, co-equal allocation between the space passive services and the Fixed and Mobile Services is feasible. The criteria for sharing with digital fixed and mobile systems is that these systems conform to the specifications of CCIR Reports 387-2, 609, and 610.

SECTION 23

FREQUENCY BAND 300-303 GHz

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 300-303 GHz BAND

23.1 ALLOCATIONS

There are no existing international allocations above 275 GHz. The proposed allocations in the 300-303 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions.

Region 1	Region 2	Region 3
	GOVERNMENT	
300-303	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive)	
	NON-GOVERNMENT	
300-310	AMATEUR AMATEUR-SATELLITE	

23.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric nitrous oxide (primary)

23.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

23.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

23.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- **Limb Scanning Nitrous Oxide**

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per week
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.3 x 1.25 meter (limb scanning)

- **Operational Requirements**

Limb nitrous oxide constituent measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

23.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use is expected in the mid-1980's.

23.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric nitrous oxide profile measurements. This band was selected because it contains a nitrous oxide rotation line at 301.4 GHz.

The required bandwidth (1850 MHz) is determined by radiometer sensitivity, receiver noise temperature, and integration time, all of which are fixed by the application. A derivation of the bandwidth value is contained in Chapter II, Part B, Section 23.

23.8 SHARING ANALYSIS RESULTS

The 300 to 303 GHz band is currently not allocated. Proposed allocations are for Amateur and Amateur-Satellite Services in addition to the passive services.

The results presented herein are based on an estimate of technological advances and regulatory policies on possible amateur operations in the band. The assumptions underlying this analysis are that:

- Amateur usage will not employ transmitter powers in excess of those permitted by regulations currently in force.
- Technology will impose certain limitations on antenna gain.
- No Amateur - Satellite transmitters will be established in this band within the forseeable future due to limitations of technology and expense.

A summary of the results of the sharing analysis are presented below and in Table 23-1. The detailed sharing analyses are presented in Chapter II, Part B, Section 23.

Harmful interference will not be encountered due to operations of transmitters in the Amateur Service.

23.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis in the 300-303 GHz band between spaceborne passive sensors and terrestrial stations in the Amateur Service is feasible.

Consequently, a primary, co-equal allocation is feasible.

TABLE 23-1

SUMMARY OF SHARING ANALYSES RESULTS

		AMATEUR
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-18
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-157
LOSS OF COVERAGE AREA FROM SINGLE INTERFEROR	(km^2)	-
	%	-
SIMULTANEOUS SHARING FEASIBLE		YES

* (-) Indicates below interference threshold of -150 dB(W).

SECTION 24

FREQUENCY BAND 320-330 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

320-330 GHz BAND

24.1 ALLOCATIONS

There are no existing international allocations above 275 GHz. The proposed allocations in the 320-330 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions.

Region 1	Region 2	Region 3
	GOVERNMENT	
<u>320-330</u>	<u>EARTH EXPLORATION SATELLITE (Passive)</u> <u>SPACE RESEARCH (Passive)</u> <u>RADIO ASTRONOMY</u>	
	NON-GOVERNMENT	
<u>310-330</u>	<u>AMATEUR</u>	

24.2 MEASUREMENT

Thermal microwave earth emissions t determine:

1) Stratospheric water vapor (primary)

24.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

24.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

24.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Sounder Water Vapor Observations

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Soil Moisture (1.4, 2.7 GHz), Snow Morphology (1.4, 2.7, 10.7, 14.9, 37 GHz), Sea State (10.7, 19.9 GHz), Sea Ice (1.4, 10.7, 19.9 GHz), Clouds (37, 90 GHz), Rain (19.9, 37 GHz), Atmospheric Temp. (52 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.3 x 1.25 meter (limb scanning)

- **Operational Requirements**

Limb water vapor measurements are required once per day. Continuous spacecraft measurements are required to compile this data.

24.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are continuing on Microwave Limb Sounder for use on meteorological-satellites. Operational use is expected in the mid-1980's.

24.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric water vapor profile measurements. This band was selected because it contains a water vapor rotation line at 325.1 GHz.

The overall required bandwidth for this frequency was selected to provide multiple channel observations within the band to measure water vapor at various altitudes. Each channel requires a bandwidth of 1850 MHz. A derivation of this bandwidth is contained in Chapter II, Part B, Section 24.

24.8 SHARING ANALYSIS RESULTS

The 320 to 330 GHz band is currently not allocated. Proposed allocations include the Amateur Service in addition to the passive services.

The results presented herein are based on an estimate of the technological advances and regulatory policy influence on possible amateur operations in the band. The assumptions underlying this analysis are that:

- Amateur usage will not employ powers in excess of those permitted by regulations currently in force.
- Technology will impose limitations on antenna gain.

The results of the sharing analysis are presented below and in Table 24-1. The detailed sharing analyses can be found in Chapter II, Part B, Section 24.

Harmful interference will not be encountered due to operations of transmitters in the Amateur Service.

24.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis in the 320-330 GHz band between spaceborne passive sensors and terrestrial stations in the Amateur Service is feasible.

Consequently, a primary, co-equal allocation is feasible.

TABLE 24-1

SUMMARY OF SHARING ANALYSES RESULTS

		AMATEUR SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-19
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-158
LOSS OF COVERAGE AREA FROM SINGLE INTERFEROR	km^2	-----
	%	-----
SIMULTANEOUS SHARING FEASIBLE		YES

*(-) Indicates below interference threshold of -150 dB(W).

SECTION 25

FREQUENCY BAND 340 - 350 GHz

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 340-350 GHz BAND

25.1 ALLOCATIONS

There are no existing international allocations above 275 GHz. The proposed allocations are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions.

Region 1	Region 2	Region 3
	GOVERNMENT	
340-350	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) RADIO ASTRONOMY	
	NON-GOVERNMENT	
340-350 GHz	RADIO ASTRONOMY	

25.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric carbon monoxide (primary)

25.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

25.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

25.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Sounder Carbon Monoxide Observations

Range:	------
Accuracy:	------
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per week
Intergration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.25 x 1.0 meter (limb scanning)

- **Operational Requirements**

Limb carbon monoxide measurements are required once per week. Continuous spacecraft measurements are required to compile this data.

25.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on the Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use of this band is expected in the mid-80's.

25.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric carbon monoxide profile measurements. This band was selected because it contains a carbon monoxide rotation line at 345.8 GHz.

The overall required bandwidth for this frequency was selected to provide multiple channel observations within the band to measure carbon monoxide at various altitudes. Each channel requires a bandwidth of 1850 MHz; a derivation of this bandwidth is contained in Chapter II, Part B, Section 25.

25.8 SHARING ANALYSIS RESULTS

The 340-340 GHz frequency band is not currently allocated to any service. It is proposed that this band be shared between the Earth Exploration Satellite (passive), Space Research (passive) and Radio Astronomy Services. Since the above passive services can inherently share the band, frequency sharing in the 340-350 GHz band is feasible.

25.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis between spaceborne passive microwave sensors and the Earth Exploration Satellite (passive), Space Research (passive), and Radio Astronomy Services is feasible.

Consequently, a primary, co-equal allocation is feasible.

SECTION 26

FREQUENCY BAND 360 - 370 GHz

ANALYSIS OF PASSIVE REMOTE SENSING REQUIREMENTS IN THE 360-370 GHz BAND

26.1 ALLOCATIONS

There are no existing international allocations above 275 GHz. The proposed allocations in the 360-370 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions.

Region 1	Region 2	Region 3
	GOVERNMENT	
360-370	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) RADIO ASTRONOMY	
	NON-GOVERNMENT	
360-402	AMATEUR	

26.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric ozone (primary)

26.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

26.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

26.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Sounder Ozone Observations

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Water Vapor (22.4 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.25 x 1.0 meter (limb scanning)

- **Operational Requirements**

Limb ozone measurements are required once per day. Continuous spacecraft measurements are required to compile this data.

26.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use is expected in the mid-1980's.

26.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric ozone profile measurements. This band was selected because it contains a ozone rotation line at 364.4 GHz.

The overall required bandwidth for this frequency was selected to provide multiple channel observations within the band to measure ozone at various altitudes. Each channel requires a bandwidth of 1850 MHz; a derivation of this bandwidth is contained in Chapter II, Part B, Section 26.

26.8 SHARING ANALYSIS RESULTS

The 360 to 370 GHz band is currently not allocated, and is proposed for allocation to the Amateur Service in addition to the passive services.

The results presented herein are based on an estimate of technological advances and regulatory policy influence on possible amateur operations in the band. The assumptions underlying this analysis are that:

- Amateur usage will not employ powers in excess of those permitted by regulations currently in force.

- Technology will impose certain limitations on antenna gain.

The results of the sharing analysis are presented below. and in Table 26-1. The detailed sharing analyses can be found in Chapter II, Part B, Section 26.

Harmful interference will not be encountered during simultaneous operation of transmitters in the Amateur Service.

26.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis in the 360-370 GHz band between spaceborne passive sensors and terrestrial stations in the Amateur Service is feasible.

Consequently, a primary, co-equal allocation is feasible.

TABLE 26-1

SUMMARY OF SHARING ANALYSES RESULTS

		AMATEUR SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-20
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		- 159
LOSS OF COVERAGE AREA FROM SINGLE INTERFEROR	km^2	-----
	%	-----
SIMULTANEOUS SHARING FEASIBLE		YES

*(-) Indicates below interference threshold of -150 dB(W).

SECTION 27

FREQUENCY BAND 375 - 385 GHz

ANALYSIS OF PASSIVE REMOTE SENSING

REQUIREMENTS IN THE

375-385 GHz BAND

27.1 ALLOCATIONS

There are no existing international allocations above 275 GHz. The proposed allocations in the 375-385 GHz frequency band are given below for ITU Regions 1, 2, and 3. Underlined items indicate proposed additions.

Region 1	Region 2	Region 3
	GOVERNMENT	
375-385	EARTH EXPLORATION SATELLITE (Passive) SPACE RESEARCH (Passive) RADIO ASTRONOMY	
	NON-GOVERNMENT	
360-402	AMATEUR	

27.2 MEASUREMENT

Thermal microwave earth emissions to determine:

1) Stratospheric water vapor (primary)

27.3 APPLICATION

More effective and efficient management of:

1) Environmental regulations
2) Air pollution (stratospheric)

27.4 GEOGRAPHICAL COVERAGE REQUIREMENTS

Measurements are required over all areas of the globe.

27.5 SENSOR PERFORMANCE AND ORBITAL REQUIREMENTS

- Limb Sounder Water Vapor Observations

Range:	-----
Accuracy:	-----
Sensitivity:	0.2 K
Resolution:	1 km (vertical)
Update Rate:	1 per day
Integration Time:	1 second
Bandwidth:	1850 MHz
Sensor Interference Threshold:	-150 dB(W)
Competing Effects:	Soil Moisture (1.4, 2.7 GHz), Snow Morphology (1.4, 2.7, 10.7, 19.9, 37 GHz), Sea State (10.7, 19.9 GHz), Sea Ice (1.4, 10.7, 19.9 GHz) Clouds (37, 90 GHz) Rain (19.9, 37 GHz) Atmospheric Temperature (52 GHz)

- **Spacecraft Parameters**

Orbital Altitude:	500 km, circular
Inclination:	70-110° (for world-wide coverage)
Antenna:	0.25 x 1.0 meter (limb scanning)

- **Operational Requirements**

Limb water vapor measurements are required once per day. Continuous spacecraft measurements are required to compile this data.

27.6 STATUS OF TECHNOLOGY AND USE

Current development and testing are proceeding on Microwave Limb Sounder for the Shuttle and meteorological-satellites. Operational use is expected in the mid-1980's.

27.7 REASONS FOR SELECTION OF THIS FREQUENCY AND BANDWIDTH

This band is required for stratospheric water vapor profile measurements. This band was selected because it contains a water vapor rotation line at 380.2 GHz.

The overall required bandwidth for this frequency was selected to provide multiple channel observations within the band to measure water vapor at various altitudes. Each channel requires a bandwidth of 1850 MHz; a derivation of this bandwidth is contained in Chapter II, Part B, Section 27.

27.8 SHARING ANALYSIS RESULTS

The 375 to 385 GHz band is currently not allocated, and is proposed for allocation to the Amateur Service in addition to the passive services.

The results presented herein are based on an estimate of technological advances and regulatory policy influence on possible amateur operations in the band. The assumptions underlying this analysis are that:

- Amateur systems will not employ powers in excess of those permitted by regulations currently in force.
- Technology will impose limitations on antenna gain.

The results of the sharing analysis are presented below and in Table 27-1. The detailed sharing analysis is presented in Chapter II, Part B, Section 27.

Harmful interference will not be encountered during simultaneous operation of transmitters in the Amateur Service.

27.9 SHARING CONCLUSIONS

Sharing on a simultaneous operational basis in the 375-385 GHz band between spaceborne passive sensors and terrestrial stations in the Amateur Service is feasible.

Consequently, a primary, co-equal allocation is feasible.

TABLE 27-1

SUMMARY OF SHARING ANALYSES RESULTS

		AMATEUR SERVICE
MAXIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		- 20
MINIMUM RECEIVED POWER (dB RELATIVE TO THE INTERFERENCE THRESHOLD*) FOR ONE INTERFEROR		-159
LOSS OF COVERAGE AREA FROM SINGLE INTERFEROR	km^2	-----
	%	-----
SIMULTANEOUS SHARING FEASIBLE		YES

*(-) Indicates below interference threshold of -150 dB(W).